

(E79-10181) **NATIONWIDE FORESTRY
APPLICATIONS PROGRAM. TEN-ECOSYSTEM STUDY**
(TES) SITE 6, FORT YUKON, ALASKA Final
Report (Lockheed Electronics Co.) 87 p HC
A05/MF A01 CSCL 08F G3/43 00181

N79-20452 FEB 28 1979

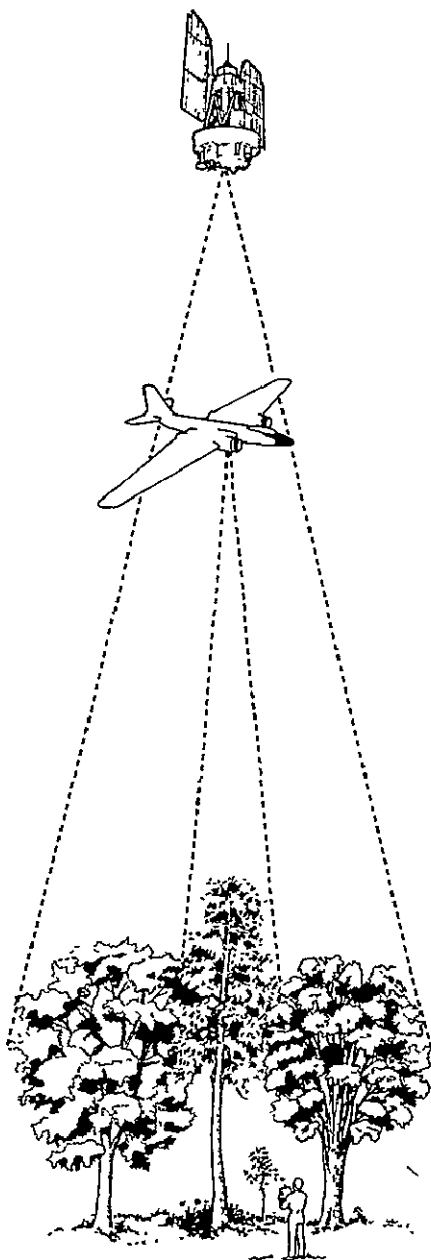
Unclass

10181

NATIONWIDE FORESTRY APPLICATIONS PROGRAM

NASA CR-

160131



TEN-ECOSYSTEM STUDY (TES) SITE VI, FORT YUKON, ALASKA, FINAL REPORT

J. F. Ward and B. F. Edwards
Lockheed Electronics Company, Inc.
Systems and Services Division
Houston, Texas 77058

“Made available under NASA sponsorship
in the interest of early and wide dis-
semination of Earth Resources Survey
Program information and without liability
for any use made thereof.”

Contract NAS 9-15200
JSC-12693
LEC-12567
December 1978

Prepared for
EARTH OBSERVATIONS DIVISION
SPACE AND LIFE SCIENCES DIRECTORATE
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER
HOUSTON, TEXAS 77058

NASA

National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston Texas 77058



FOREST SERVICE
U.S. Department of Agriculture

NOTE: In 1976, the Nationwide Forestry Applications Program was expanded from a Regional project by cooperative agreement between the Forest Service, U. S. Department of Agriculture, and the National Aeronautics and Space Administration (NASA). The Program is designed to sponsor research and development on the application of remote sensing analysis techniques to problems arising from the need to inventory, monitor and manage forests and rangelands, including the assessment of impacts on forest stands from insect and disease damage.

1 Report No. JSC-12693		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle Ten-Ecosystem Study (TES) Site VI, Fort Yukon, Alaska, Final Report				5 Report Date December 1978	
				6 Performing Organization Code	
7. Author(s) J. F. Ward and B. F. Edwards Lockheed Electronics Company, Inc.				8 Performing Organization Report No. LEC-12567	
				10. Work Unit No.	
9 Performing Organization Name and Address Lockheed Electronics Company, Inc. Systems and Services Division 1830 NASA Road 1 Houston, Texas 77058				11. Contract or Grant No. NAS 9-15200	
				13 Type of Report and Period Covered Type II Final Report	
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Lyndon B. Johnson Space Center Houston, Texas 77058 Technical Monitor: R. E. Joosten				14 Sponsoring Agency Code	
15 Supplementary Notes					
16 Abstract This final report presents the findings, conclusions, and recommendations obtained from the automatic data processing analysis of Landsat and photographic data acquired over Fort Yukon, Alaska (Site VI of the Ten-Ecosystem Study). This site was selected to be representative of the Boreal Ecosystem. The analysis of the processing results has led to the following conclusions: a. Landsat imagery is a reliable resource for the stratification of Level II forest features (softwood, hardwood, tundra, and water). These features can be classified with an accuracy of 72.4 percent $\pm$ 5.9 percent at the 90-percent confidence level. b. Training fields selected for signature development from only 10 percent of the area do not adequately and efficiently cover the class variability for the entire area. c. Derived regression transformations are ineffective in recovering the loss of Level I forest proportions and Level II softwood and hardwood proportions.					
17 Key Words (Suggested by Author(s)) Alaska Forestry Inventory Remote sensing			18 Distribution Statement Original photography may be purchased from EROS Data Center Sioux Falls, SD 57198		
19 Security Classif. (of this report) Unclassified		20. Security Classif. (of this page) Unclassified		21. No. of Pages 87	
				22. Price*	

*For sale by the National Technical Information Service, Springfield, Virginia 22161

PREFACE

The Nationwide Forestry Applications Program was established in 1971 at the Lyndon B. Johnson Space Center of the National Aeronautics and Space Administration to develop and to demonstrate the use of remote sensing technology in performing forestry resources inventories, with particular application to the Forest Service of the U.S. Department of Agriculture. During the 1971-75 time period, many small and localized studies were conducted on the feasibility of using automatic data processing techniques and conventional photointerpretation analysis for forestry applications. The studies were directed primarily toward specific applications for Region VIII of the Forest Service.

The need for extending the technology to intermediate-scale and large-scale applications was reflected in the passage of the Forest and Rangeland Renewable Resources Planning Act of 1974 (Public Law 93-378). In response to some of the research requirements of this act, the Ten-Ecosystem Study was initiated to investigate the feasibility of analyzing forest and grassland ecosystems on a regional scale using automatic data processing techniques. This study analyzes Landsat data, supporting aircraft imagery, and ancillary information to inventory forest, grassland, and water areas by administrative boundaries in 10 broad ecosystems of the United States. For each specific ecosystem, analysis success, problems, and failures are clearly and objectively identified, and recommendations are made for future large-area inventory analyses. Recommendations on the definition and requirements of a preliminary integrated automatic data processing analysis system to inventory nationwide forest and rangeland renewable resources are also made.

PRECEDING PAGE BLANK NOT FILLED

The primary objectives of the Ten-Ecosystem Study are:

- a. To investigate the feasibility of using the automatic processing of remotely sensed data to inventory forest, grassland, and inland water areas within administrative boundaries for specified ecosystems of the United States
- b. To identify automatic data processing analysis problems related to each ecosystem and recommend solutions
- c. To define the requirements for an automatic data processing system to perform a nationwide forest and grassland inventory .

These objectives will be addressed in the Ten-Ecosystem Study final report to be published in December 1978, after the data for the individual sites have been processed and analyzed.

The current report discusses the analysis of the Fort Yukon, Alaska, site, which was selected to represent the Boreal Ecosystem. The topics covered include data compilation, site familiarization, and data processing. This report was prepared by Lockheed Electronics Company, Inc., under Contract NAS 9-15200, Job Order 75-325, Action Document 63-1737-5325-45. It is the final of four reports covering the study conducted at the Fort Yukon, Alaska, site. Distribution of this report has been approved by the supervisor of the Forestry Applications Section and the manager of the Earth Observations Exploratory Studies Department.

CONTENTS

Section	Page
ABBREVIATIONS	xiii
1. INTRODUCTION.	1-1
2. PRELIMINARY ANALYSIS AND SITE FAMILIARIZATION	2-1
2.1 <u>SITE DESCRIPTION</u>	2-1
2.1.1 LOCATION	2-2
2.1.2 PHYSIOGRAPHY AND TOPOGRAPHY.	2-2
2.1.3 VEGETATION	2-3
2.1.4 CLIMATE.	2-6
2.1.5 GEOLOGY.	2-7
2.1.6 SOIL	2-7
2.2 <u>SITE FAMILIARIZATION</u>	2-8
2.3 <u>CARTOGRAPHIC DATA</u>	2-9
2.4 <u>HIERARCHY OF FEATURES</u>	2-10
2.4.1 AERIAL PHOTOINTERPRETATION	2-10
2.4.2 LANDSAT IMAGERY.	2-11
3. PREPROCESSING	3-1
3.1 <u>IMAGE-TO-IMAGE REGISTRATION</u>	3-1
3.2 <u>IMAGE-TO-GROUND REGISTRATION</u>	3-2
3.3 <u>SCALE FACTOR AND PIXEL SIZE</u>	3-2
3.4 <u>ADMINISTRATIVE BOUNDARIES</u>	3-2
3.5 <u>TRAINING FIELD SELECTION</u>	3-3

Section	Page
4. PROCESSING.	4-1
4.1 <u>SEPARABILITY STUDY</u>	4-2
4.1.1 SELECTION OF BANDS FOR PROCESSING THE TEMPORAL DATA.	4-2
4.1.2 MASTER SIGNATURE	4-2
4.1.3 TRAINING FIELD ACCURACIES.	4-2
4.1.4 LEVEL III CLASSIFICATION	4-3
4.2 <u>SIMULATED INVENTORY STUDY</u>	4-4
5. POSTPROCESSING.	5-1
5.1 <u>PASSIVE MICROWAVE IMAGING SYSTEM/DATA ANALYSIS SYSTEM FALSE-COLOR FILMING.</u>	5-1
5.2 <u>UNIVAC 1110</u>	5-2
5.3 <u>PSU LOCATION</u>	5-2
5.4 <u>FINAL OUTPUT PRODUCT</u>	5-2
6. EVALUATION.	6-1
7. DIRECT RESOURCE UTILIZATION	7-1
8. ANALYSIS OF RESULTS	8-1
8.1 <u>SOFTWOOD ANALYSIS</u>	8-2
8.2 <u>HARDWOOD ANALYSIS</u>	8-4
8.3 <u>TUNDRA ANALYSIS</u>	8-5
8.4 <u>WATER ANALYSIS</u>	8-6
8.5 <u>LEVEL I REPRESENTATION</u>	8-6
9. CONCLUSIONS AND RECOMMENDATIONS	9-1
9.1 <u>CONCLUSIONS</u>	9-1
9.1.1 OPTIMAL DATA FOR LANDSAT IMAGERY	9-1
9.1.2 TYPE MAPPING ACCURACIES.	9-2

Section	Page
9.1.3 SPECIFIC SITE PROBLEMS.	9-3
9.1.4 FEASIBILITY OF ADP REMOTE SENSING TO LARGE AREA INVENTORY OF FOREST, TUNDRA, AND WATER	9-4
9.2 <u>RECOMMENDATIONS</u>	9-4
10. REFERENCES	10-1

TABLES

Table		Page
2-1	LEVEL II VEGETATION CLASSES IN FORT YUKON, ALASKA	2-14
2-2	CLASSIFICATION SYSTEM FOR INTERPRETATION OF AIRCRAFT PHOTOGRAPHY	2-15
4-1	SUMMARY OF TRAINING FIELD CLASSIFICATION ACCURACIES FOR THE SEPARABILITY AND INVENTORY STUDIES.	4-5
4-2	SUMMARY OF TRAINING FIELD CLASSIFICATION ACCURACY FOR THE LEVEL III SEPARABILITY STUDY. . .	4-5
4-3	SUMMARY OF CLASSIFICATION RESULTS, FORT YUKON, ALASKA	4-6
6-1	ESTIMATED PCC AND CONFIDENCE INTERVAL AT THE 90-PERCENT CONFIDENCE LEVEL FOR 25 PSU'S	6-2
6-2	AVERAGE ERRORS (B) BETWEEN CLASS PROPORTION ESTIMATES FROM AERIAL PHOTOINTERPRETATION AND LANDSAT ADP INVENTORY CLASSIFICATION OF FORT YUKON, ALASKA, TEST SITE	6-3
6-3	REGRESSION ESTIMATES OF PROPORTION AND ASSOCIATED PRECISION	6-4
7-1	RESOURCES UTILIZED FOR SITE PROCESSING	7-2
7-2	DIRECT COSTS FOR MACHINE TIME AND MAN-HOURS. . . .	7-3
8-1	INVENTORY AND PHOTOGRAPH SAMPLE DATA FOR SOFTWOOD PROPORTIONS	8-8
8-2	INVENTORY AND PHOTOGRAPH SAMPLE DATA FOR HARDWOOD PROPORTIONS	8-9
8-3	INVENTORY AND PHOTOGRAPH SAMPLE DATA FOR TUNDRA PROPORTIONS	8-10
8-4	INVENTORY AND PHOTOGRAPH SAMPLE DATA FOR WATER PROPORTIONS.	8-11
8-5	RECAPITULATION OF LEVEL I AND LEVEL II PROPORTION ESTIMATES	8-12

FIGURES

Figure		Page
2-1	Location of the test site.	2-17
2-2	Location of the test site on the Army Map Service 1:250 000-scale Black River map.	2-19
2-3	Closed, tall spruce, and deciduous forest.	2-21
2-4	Open, low, mixed evergreen, and deciduous forest	2-21
2-5	Bogs and marshes	2-23
2-6	Tall shrub thickets.	2-23
2-7	Low shrub thickets	2-25
2-8	Moist sedge and grass vegetation	2-25
2-9	Training fields and aerial reconnaissance route of the field survey teams.	2-27
2-10	Stereogram of a portion of the Alaska study site	2-29
2-11	Color infrared aerial photograph of a portion of the Alaska study site and overlay	2-31
2-12	August Landsat color composite indicating the Alaska study site.	2-33
2-13	September Landsat color composite indicating the Alaska study site.	2-35
2-14	March Landsat color composite indicating the Alaska study site.	2-37
5-1	Inventory classification of Level II features of quadrant 1 of the Alaska study site	5-5
5-2	Landsat raw data from September imagery of quadrant 1 of the Alaska study site.	5-7
5-3	Inventory classification of Level II features of quadrant 1 of the Alaska study site after running GETMIX/CLEAN	5-9

Figure		Page
5-4	Alphanumeric printout of a 50- by 50-pixel PSU. . .	5-11
5-5	Locations of the 25 PSU's in the site	5-13
5-6	Final classification map.	5-15
8-1	Summary of proportion estimates and 90-percent confidence intervals.	8-13
8-2	Proportion estimates for softwood	8-14
8-3	Proportion estimates for hardwood	8-15
8-4	Proportion estimates for tundra	8-16
8-5	Proportion estimates for water.	8-17

ABBREVIATIONS

ADP	automatic data processing
ERIPS	Earth Resources Interactive Processing System
Image 100	Interactive Multispectral Image Analysis System, Model 100
JSC	Lyndon B. Johnson Space Center
NASA	National Aeronautics and Space Administration
NFAP	Nationwide Forestry Applications Program
PCC	percent of correct classification
pixel	picture element
PMIS/DAS	Passive Microwave Imaging System/Data Analysis System
PSU	primary sampling unit
SSU	secondary sampling unit
TES	Ten-Ecosystem Study
USDA	U.S. Department of Agriculture

1. INTRODUCTION

The analysis tasks and objectives of the Ten-Ecosystem Study (TES), as defined in the technical analysis procedures (ref. 1), are listed below:

a. Task I.5, Preliminary Analysis

- To establish the best seasons for automatic data processing (ADP)
- To provide initial site familiarization
- To provide cognizance of the temporal vegetation changes

b. Task II.1, Data Compilation and Site Familiarization

- To gather relevant information and learn as much as possible about the site
- To conduct a 1-week site familiarization trip

c. Task II.2, Preprocessing

- To register Landsat data sets for two dates
- To register Landsat data on an appropriate map system
- To delineate training areas on Landsat imagery

d. Task II.3, Processing

- To select training signatures from all available data for Level II and Level III classification (This is referred to as the separability study.)
- To select training signatures from 10 percent of the area to be used for Level II classification of the entire site (The purpose of this simulated inventory study is to test signature extension.)

e. Task II.4, Postprocessing and Output Products

- To furnish specific output classification data from task II.3
- To produce final output products in the forms of color films, transparencies, prints, and color-coded classification maps

f. Task II.5, Evaluation

To evaluate the accuracy and precision of the classification maps produced from task II.2

Site VI of the TES, which is representative of the Boreal Ecosystem, is in Fort Yukon, Alaska. It is located on the Arctic Circle, 40 kilometers (25 miles) from the Canadian border on the eastern edge of the proposed Porcupine National Forest. The area is characterized physiographically by rolling hills, broad valleys, and waterlogged brush or tundra. Typical forest types are white spruce, black spruce, and such northern hardwoods as aspen, willow, balsam poplar, and paper birch.

This report presents the results and conclusions of the TES analysis tasks as they pertain to Site VI. The tables and figures explaining the material are included at the end of each section.

2. PRELIMINARY ANALYSIS AND SITE FAMILIARIZATION

The preliminary analysis and site familiarization tasks were designed to establish the two Landsat dates to be used for computer analysis and to provide firsthand ground information and background data on site vegetation, soil, geology, and forest management practices.

The objectives of the preliminary analysis were:

- a. To establish the best seasons for the ADP analysis of Landsat color composite frames
- b. To provide initial site familiarization as a basis for selecting training fields and identifying anomalous areas to be ground checked
- c. To provide information on the changes in vegetation characteristics with time

The objectives of the site familiarization task included:

- a. Collecting information on site soils, climate, vegetation, geology, and forest management practices
- b. Contacting U.S. Department of Agriculture (USDA) Forest Service personnel at the site for firsthand information on site characteristics and accessibility
- c. Visiting prospective training field locations to analyze the vegetation patterns (ref. 1)

The procedures and results for these tasks are described in the succeeding sections.

2.1 SITE DESCRIPTION

Ancillary data on the location, physiography and topography, vegetation, climate, and geology of the study site were collected

to help prepare TES scientists for their visit to the area. These data are described below.

2.1.1 LOCATION

The site is a square 60 by 60 kilometers (37 by 37 miles) in size. It is located in the Yukon Province of Alaska, near the villages of Chalkytsik and Fort Yukon, about 80 kilometers (50 miles) west of the Canadian border (figs. 2-1 and 2-2). It is bisected by the Arctic Circle, and a portion of the site lies within the proposed Porcupine National Forest. The study site is extremely remote; there are no cultural developments such as roads, airstrips, homes, or villages (ref. 2).

The corner coordinates of the test site are:

66°25' N., 143°25' W.

66°55' N., 142°50' W.

66°42' N., 141°32' W.

66°13' N., 142°10' W.

2.1.2 PHYSIOGRAPHY AND TOPOGRAPHY

The Porcupine Plateau and the Yukon Flats are two distinct physiographic provinces. The study site chosen by the Nationwide Forestry Applications Program (NFAP) is in a transition area between these two provinces. The broad river bottoms possess many of the same characteristics as the Yukon Flats; however, the largest portion of the site is in the Porcupine Plateau.

The plateau contains low ridges, moderate slopes, and rounded summits. Most of the hills are 457 to 762 meters (1500 to 2500 feet) in elevation, and the valleys are broad and irregular. The plateau is drained by the Yukon River and its tributary,

the Porcupine River. The southern portion of the test site is drained by the Black and Little Black Rivers, which wind through broad, irregular flats (fig. 2-2).

To the south and west of the site lie the Yukon Flats, a marshy, alluvial flood plain. This is an extensive lowland which contains many lakes, potholes, oxbows, meanders, and muskeg. Except for the land along the Yukon River and its major tributaries, the Yukon Flats are underlain by permafrost.

2.1.3 VEGETATION

Because the study site includes two physiographic provinces, several different vegetation classes may be found. The succession of subecosystems caused by fire in the uplands and a changing riverbed in the lowlands also play major roles in the determination of species.

The interior of Alaska has always been extremely susceptible to wildfires, which interrupt the natural succession of forest species and cause the forest to have a mosaic appearance when viewed from the air. Many variables pertain to the regeneration of the land following a fire: (1) the burning of the organic layer (if one exists), which melts the permafrost; (2) the type of forest surrounding the burn; and (3) the aspect of the terrain. Therefore, it is very difficult to define consistent stages of succession. However, the willow is the most common species to colonize after a burn.

The dominant tree species on the site are white spruce, black spruce, quaking aspen, balsam poplar, paper birch, and various types of willow. The older river terraces are dominated by black spruce stands until the permafrost undergoes shallow thawing, creating a bog and an open black spruce muskeg.

The major vegetation types that analysts expected to find in the study site are described in reference 3 and are summarized in the succeeding sections. All of these types were identified when the site was visited (see table 2-1).

2.1.3.1 Forest Vegetation

2.1.3.1.1 Closed, Tall Spruce, and Deciduous Forests

The flood plains and terraces of the Yukon, Black, and Porcupine Rivers contain stands of well-developed and fast-growing white spruce. Paper birch and an occasional balsam poplar from an earlier successional stage occur within these stands. Some of the common shrubs are the prickly rose, the high-bush cranberry, and an occasional willow. The forest floor is covered with a thick layer of feather moss (fig. 2-3).

2.1.3.1.2 Open, Low, Mixed Evergreen, and Deciduous Forests

These forests occur on the older terraces and uplands, as well as in the wetter bottomlands. Because they are periodically burned, the uplands are generally younger than the wetter, lightly burned bottomland timber.

The forests are slower growing on the older terraces and uplands, and the stands are more open. The most common species in this vegetation type is black spruce. Other species include open stands of white spruce, which are often found in areas near the tree line, and successional stands of birch and aspen.

The wetter sites are primarily in the Yukon Flats and in the lower reaches of the Sheenjek, Porcupine, and Black Rivers. These sites contain extensive areas of black spruce muskeg that have a willow and resin birch shrub layer, as well as a ground layer of sphagnum moss, tussock sedge, and grass (fig. 2-4).

2.1.3.1.3 Bogs and Marshes

Vast areas of small lakes, which are surrounded by bogs and marshes, dominate the older river terraces. Almost pure marshes of horsetails and semiaquatic sedges are found on the wettest sites bordering the lakes; these marshes provide nesting sites and food for the waterfowl that flock to the area. The dominant types of vegetation in the bogs are sphagnum and other semiaquatic mosses; tussock sedges; grasses; and low shrubs, including bog birch, Labrador-tea, leatherleaf, and willow. The drier sites in the bogs contain occasional slow-growing paper birch, black spruce, and tamarack (fig. 2-5).

2.1.3.1.4 Tall Shrub Thickets

These thickets are found in flood plains and in areas that have been struck by wildfire. All the major rivers within the forest have extensive silt bars colonized by willow and alder. Also common are thickets of felt-leaf, little-tree willow and thin-leaf alder.

Extensive willow thickets are also found in many areas that have recently been struck by fire. These shrubs sprout from existing willow roots or from seeds distributed from the surrounding unburned areas. The most common species, Bebb willow and gray-leaf willow, usually form open stands. Exceptional moose forage is provided by these thickets for a number of years after a fire (fig. 2-6).

2.1.3.1.5 Low Shrub Thickets

In the uplands near the mouth of the Porcupine River, resin birch and willow occur extensively, forming an ecotone between the forest and the tundra. Rich lichen stands, which caribou herds use for forage, grow on this type of vegetation if it remains unburned long enough (fig. 2-7).

2.1.3.2 Tundra Vegetation

2.1.3.2.1 Moist Sedge and Grass Tundra

In some areas, tussock sedge is the primary vegetation. Such low shrubs as resin birch, Labrador-tea, and bog blueberry occur at intervals within the sedge (fig. 2-8).

2.1.3.2.2 Dry Alpine Tundra

This is the only other type of tundra found within the study site. It has little significance in this study because it is found only on the steeper slopes of the higher mountains in isolated patches (ref. 3).

2.1.4 CLIMATE

The typical climate of this Arctic area is continental, characterized by low precipitation, cloudiness, and humidity; great annual and diurnal temperature variations; and -3.8° to 1.7° C (25° to 35° F) low mean annual temperatures (ref. 3). Extended periods of -45° to -51° C (-50° to -60° F) are common, causing long and very harsh dark winters. The summers are short but warm, with temperatures ranging from approximately 27° to 32° C (80° to 90° F). However, the test site can experience freezing temperatures during any month of the year. A record high of 37° C (100° F) was recorded at Fort Yukon; a record low of -61° C (-78° F) was recorded at the same station (ref. 5).

The annual rainfall varies from about 15 to 25 centimeters (6 to 10 inches), mostly in the form of convectional showers. The average snowfall is about 114 centimeters (45 inches) per year.

The study site, which is bisected by the Arctic Circle, experiences up to 24 hours of sunlight per day during the short summer,

and its winters are long and dark. The soil and air temperatures rise very quickly in June and decrease just as quickly in August, causing plant flowering, fruiting, and growth to occur very rapidly.

2.1.5 GEOLOGY

Schist, slate, granite, quartzite, and mafic rock, probably originating in the Paleozoic Age, lie under much of the test site. Moderately deformed sedimentary rocks from the Paleozoic and Mesozoic Ages occur in other areas.

North of the site along the Porcupine River, basin-shaped formations of tertiary rocks and flows of flat-lying Cenozoic volcanic rock are found. Some limestone outcrops occur on the higher hills, and discontinuous permafrost can be found throughout the area.

The broad bed of the Black River is a finger-like extension of the Yukon Flats. Its terraces are capped with gravel, which is covered with a layer of silt (ref. 3).

2.1.6 SOIL

The test site contains a number of different soil types. The dominant ones are grouped according to the physiographic characteristics of the areas in which they are found:

a. Low-lying areas

- Deep, well-drained silty soil (*Typic Cryochrepts*)
- Deep, poorly-drained, silty loess and alluvium (*Histic Pergelic Cryaquepts*)
- Very-poorly-drained fibrous peat (*Pergelic Cryofibrists*)
- Deep, well-drained loess with silty or sandy, well-drained loam (*Typic Cryothents*)

- b. Areas with intermediate elevations and higher alluvial fans
 - Well-drained, deep, stratified, silty loam with fine, sandy loam (*Typic Fluvic Cryofluvents*)
 - Deep, well-drained silt (*Typic Cryochrepts*)
- c. Areas with rolling hills
 - Deep, poorly-drained, silty loess and alluvium (*Histic Pergelic Cryaquepts*)
 - Deep, well-drained silts (*Typic Cryochrepts*)
 - Very few outcroppings of rock

The best soils, such as the well-drained loams of the uplands and the well-drained deep silty or sandy soils of the lowland terraces, are occupied by the densest forests of white spruce, birch, aspen, and poplar. These forests have a potential commercial value.

Much of the area is underlain by permafrost which restricts the downward percolation of melted snow and rainwater, creating the poorly drained, waterlogged soils. These soils contain willow and black spruce (ref. 3).

2.2 SITE FAMILIARIZATION

After a thorough study of ancillary data on the physical characteristics of the study site, a data-gathering trip was made to the site June 12-18, 1977. The study team included two Forest Service personnel, one from Houston and one from the Institute of Northern Forestry in Fairbanks; a Houston employee of the Lyndon B. Johnson Space Center (JSC) of the National Aeronautics and Space Administration (NASA); three Houston personnel of Lockheed Electronics Company, Inc.

The team members followed the procedures for planning and executing the site familiarization trip that are given in section 3.3.2 of reference 1. At the site, these people (1) familiarized themselves with the site characteristics and anomalies, (2) field-checked preplanned locations for training signature development and for future evaluation of classification results, and (3) collected additional site data and pertinent ancillary information from the Forest Service with the help of Forest Service scientists at the Institute of Northern Forestry (ref. 1). Figure 2-9 shows the location of the training fields within the site.

A 10-percent section on the extreme eastern edge of the site was reserved for a simulated inventory and therefore was not visited during the field trip.

2.3 CARTOGRAPHIC DATA

Maps were used to locate training fields on the ground, to familiarize the TES scientists with the site, and to serve as a navigational aid while in the field. The following types of maps were used:

- a. Army Map Service¹ maps at a scale of 1:250 000 (These were used as reference bases for indexing the aerial photographs. See figure 2-1.)
- b. U.S. Geological Survey quadrangle sheets at an approximate scale of 1:60 000 (These were not available for the entire site.)

¹Now called the Defense Topographic Command.

2.4 HIERARCHY OF FEATURES

The following Level II classifications were required for the TES imagery interpretation (ref. 1):

Level I	Level II
Forest	Hardwood Softwood
Nonforest	Grassland (tundra) Water Other

2.4.1 AERIAL PHOTOINTERPRETATION

The major uses of the aircraft photographs of the site were:

- a. To make land cover classification overlays of the site
- b. To familiarize the personnel with the site
- c. To choose training fields that were checked in the field and used to train the computer
- d. To serve as an updated map to locate training fields on the ground
- e. To make a mosaic of the area

The photographs were taken on Mission 345, which was flown by NASA on August 27, 1976. Frames 136-138, 151-159, 181-189, and 199-206 were used. The film was color infrared (Kodak 2443) on 23- by 23-centimeter (9- by 9-inch) transparencies and prints at an approximate scale of 1:120 000. Figures 2-10 and 2-11 are examples of this photography.

The photographs were manually interpreted using an Old Delft scanning stereoscope. Although only Level II classifications were required, Level III classifications were also delineated

(1) to allow the interpreters to become more familiar with the site, (2) to enable the field teams to use the photographs as updated maps from which training fields can be easily located on the ground, and (3) to provide a source of ground-truth data for the possible Level III ADP classification. The classification system shown in table 2-2 was used; it was designed particularly for the Boreal Ecosystem.

The quality and the coverage of the aerial photography were very good, and there was acceptable contrast between the softwood and hardwood stands. A classification error, which was resolved after a field check, occurred when some young softwood stands of black spruce were interpreted as hardwood on the photographs; these stands displayed hardwood signatures but should have been classified as softwood. With the exception of these differences, an excellent agreement of about 98 percent was found between the photointerpretation and the ground-truth data.

2.4.2 LANDSAT IMAGERY

Available Landsat imagery was analyzed to aid in the selection of acceptable Landsat frames to be ordered and used in the ADP phase of the study. Initially, six color-composite frames of Landsat imagery were ordered, but only three of them were considered acceptable for interpretation. The following table lists the frame numbers, the dates they were taken, and the reasons why they were accepted or rejected.

Frame number	Date	Reason for elimination or acceptance	Status
1803-20265	10/04/74	80-percent snow covered	Rejected
2619-20171	10/02/76	80-percent snow covered	Rejected
1587-20333	03/02/74	50-percent snow covered (suggested for use by the Research Station of the USDA Forest Service, Juneau, Alaska)	Accepted
1407-20371	09/03/73	Good contrast, early fall	Accepted
2583-20181	08/27/76	Good contrast, early fall	Accepted
1389-20373	08/16/73	Poor contrast	Rejected

The three frames chosen are of excellent quality and were used as separate data sets. The August 1976 and September 1973 images were combined to form a temporal data set. The March 1974 frame was chosen because the leaf-off condition of the deciduous species could provide an objective estimation of spruce density. Because leafless hardwood trees do not significantly restrict snowfall, they showed no contrast with the snow-covered ground, whereas the needled softwood trees did show contrast. Therefore, the lower the amount of snow reflectance, the higher the spruce stand density. (Landsat images for August 1976, September 1973, and March 1974 are provided in figures 2-12, 2-13, and 2-14, respectively.)

An area corresponding to frame 183 of the aerial photography coverage was manually interpreted on each of the three Landsat frames using the Bausch and Lomb zoom transfer scope.

The following classifications were used:

1. Softwood
2. Hardwood
3. Mixed
4. Tundra
5. Water
6. Burned
7. Snow cover
8. Cloud cover

TABLE 2-1.— LEVEL II VEGETATION CLASSES IN
FORT YUKON, ALASKA

Class	Description
Softwood	This class consists of two coniferous species: white spruce (<i>Picea glauca</i>) and black spruce (<i>Picea mariana</i>) (refs. 3 and 4).
Hardwood	There are four species of deciduous broad-leaved trees in this class: balsam poplar (<i>Populus balsamifera</i>), quaking aspen (<i>Populus tremuloides</i>), paper birch (<i>Betula papyrifera</i>), and several different species of willow from the genus <i>Salix</i> (refs. 3 and 4).
Tundra	This class is of two types: (1) a brush tundra which includes willow and birch brush up to about 1.8 meters (6 feet) in height and (2) a grass tundra composed primarily of tussock sedge grass. These two types are often mixed (refs. 3 and 4).
Water	Rivers and lakes are scattered throughout the site. The primary rivers are the Black and Little Black Rivers.
Other	"Other" is not truly a class; it consists of all picture elements (pixels) not otherwise classified. For example, when computer processing causes some of the pixels to be thresholded out, the pixels are unclassified and placed in the "other" class. Clouds, rock, exposed soil, and other land cover for which there are no training fields are also not classified.

NOTE: Level II classes are used for ADP.

TABLE 2-2.- CLASSIFICATION SYSTEM FOR INTERPRETATION
OF AIRCRAFT PHOTOGRAPHY

Level II	Level III
1. Conifer ^a (softwood)	1. Dense 2. Medium 3. Sparse 4. Brush 5. Black spruce bog
2. Deciduous ^a (hardwood)	1. Dense 2. Medium 3. Sparse 4. Brush
3. Mixed ^a	1. Dense 2. Medium 3. Sparse 4. Brush
4. Tundra	1. Upland (heath, grass, tundra, moss) 2. Lowland (grass, moss, heath)
5. Wetlands	1. Oxbows
6. Barren	1. Exposed rock 2. Sand and gravel
7. Water	1. Lakes and ponds 2. Streams
8. Charred land	

^aWithout consideration of vegetation underneath a dense canopy.

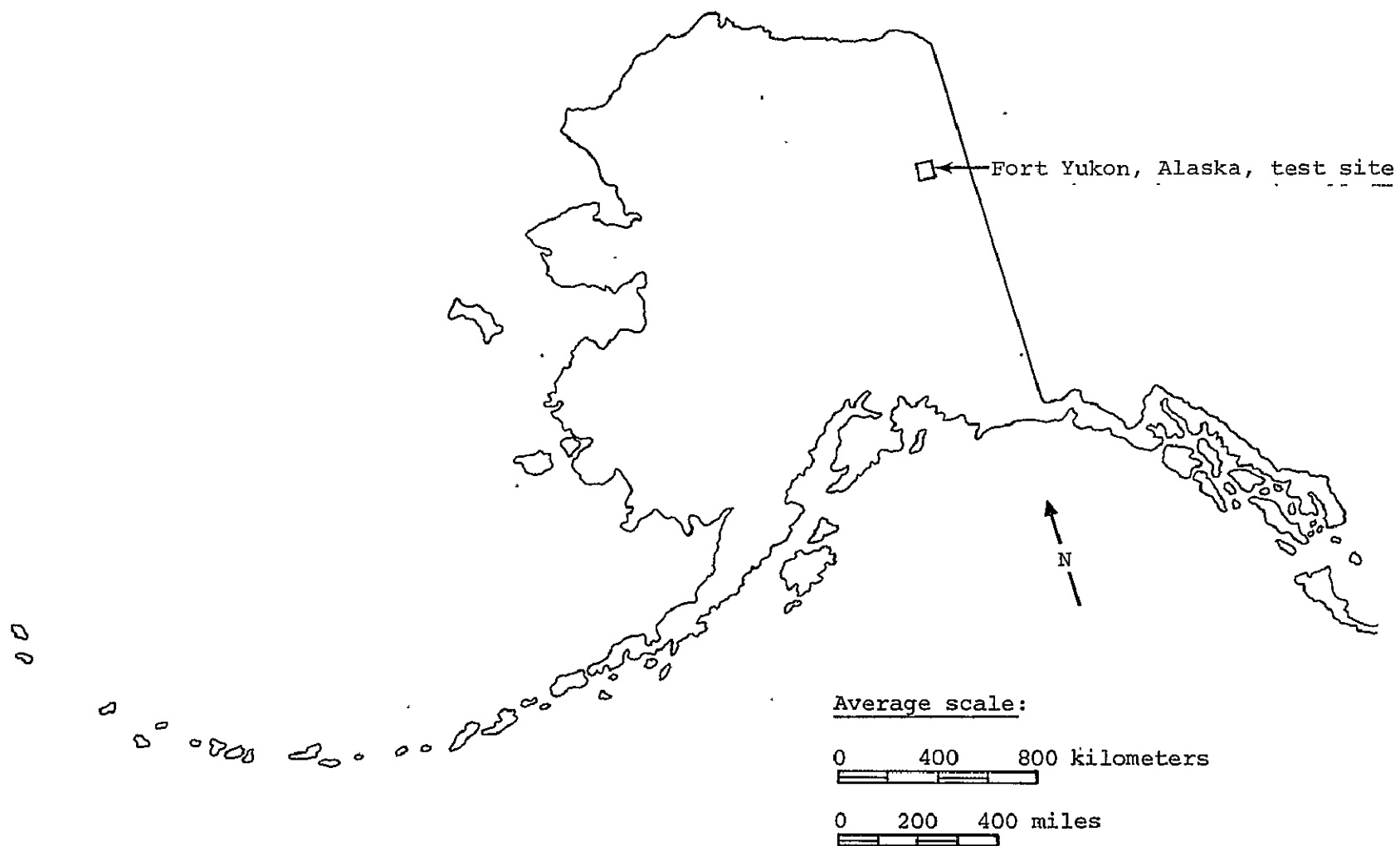
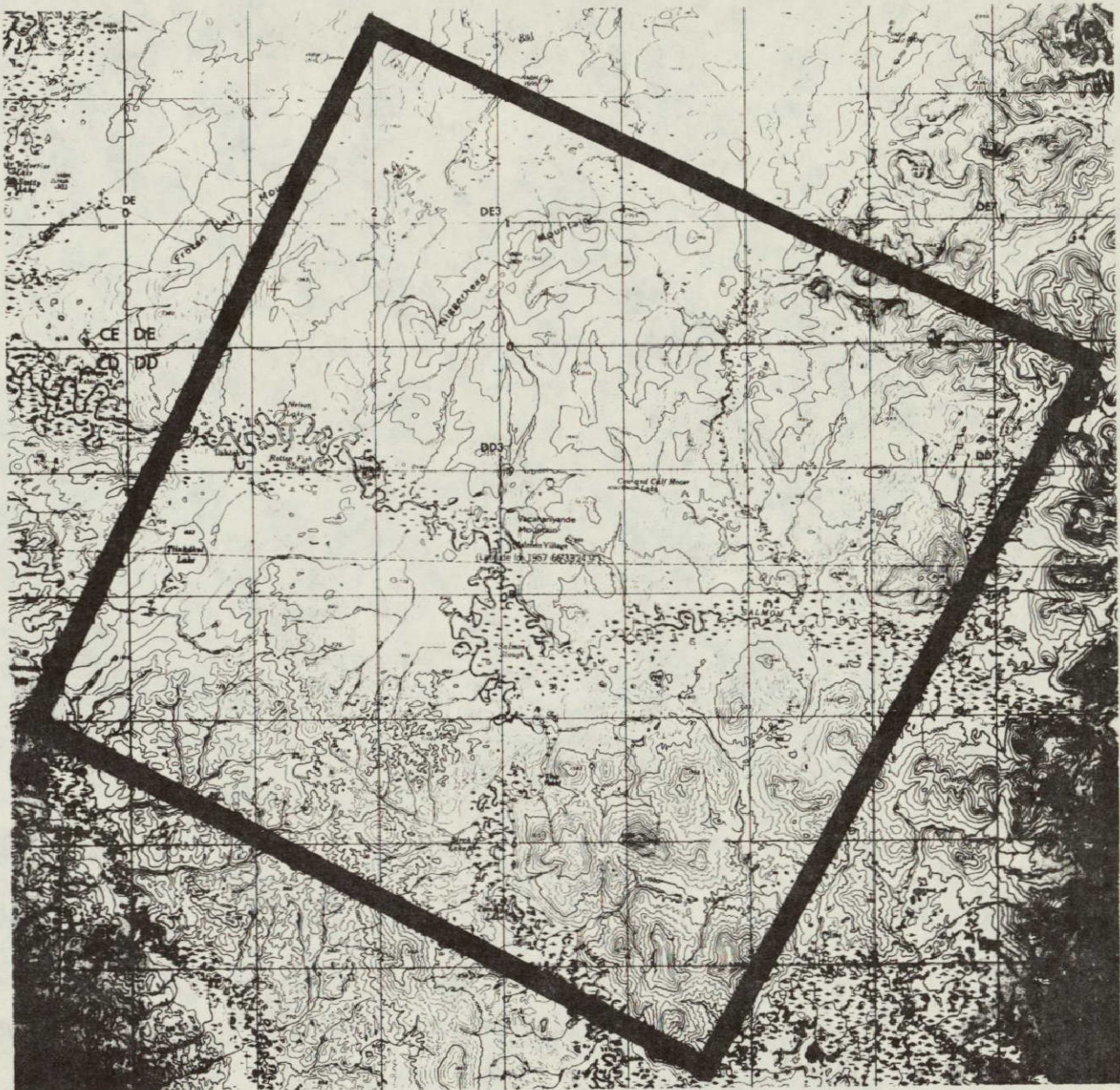


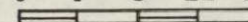
Figure 2-1.- Location of the test site.

ORIGINAL PAGE IS
OF POOR QUALITY



Average scale:

0 4 8 12 16 kilometers



0 5 10 miles

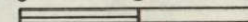


Figure 2-2.- Location of the test site on the Army Map
Service 1:250 000-scale Black River map.

(216-218)

ORIGINAL PAGE IS
OF POOR QUALITY



Figure 2-3.- Closed, tall spruce, and deciduous forest.



Figure 2-4.- Open, low, mixed evergreen, and deciduous forest.

PRECEDING PAGE BLANK NOT FILMED



Figure 2-5.- Bogs and marshes.



Figure 2-6.- Tall shrub thickets.

PRECEDING PAGE BLANK NOT FILMED

ORIGINAL PAGE IS
OF POOR QUALITY

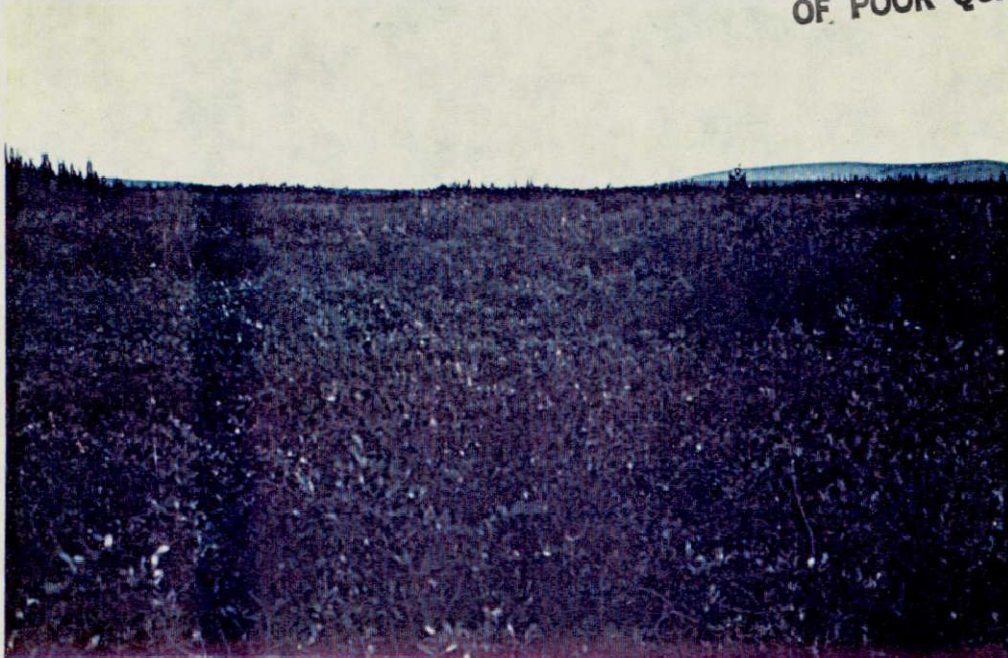


Figure 2-7.- Low shrub thickets.

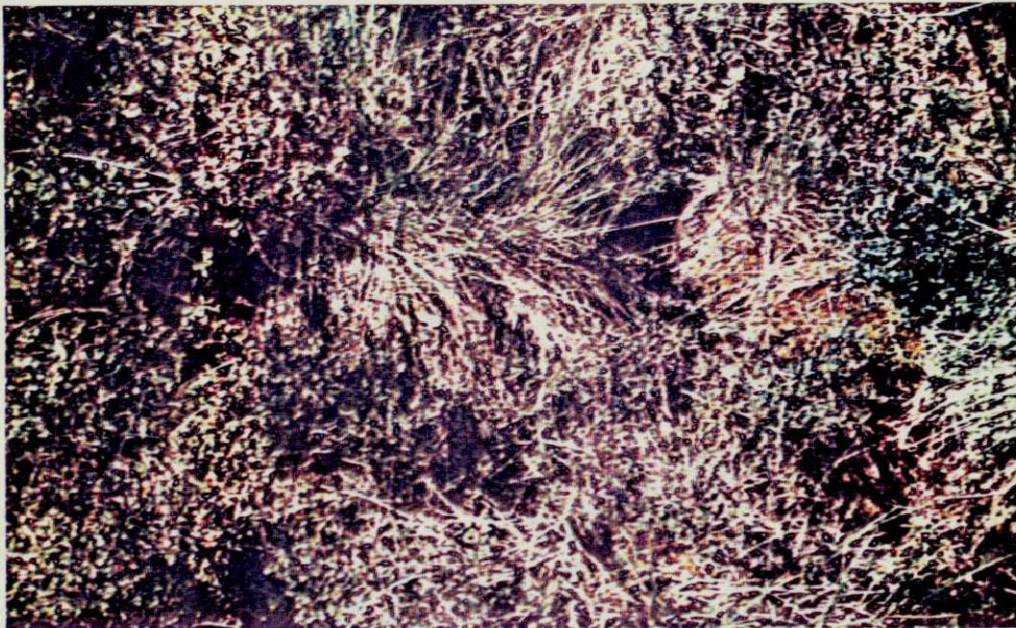
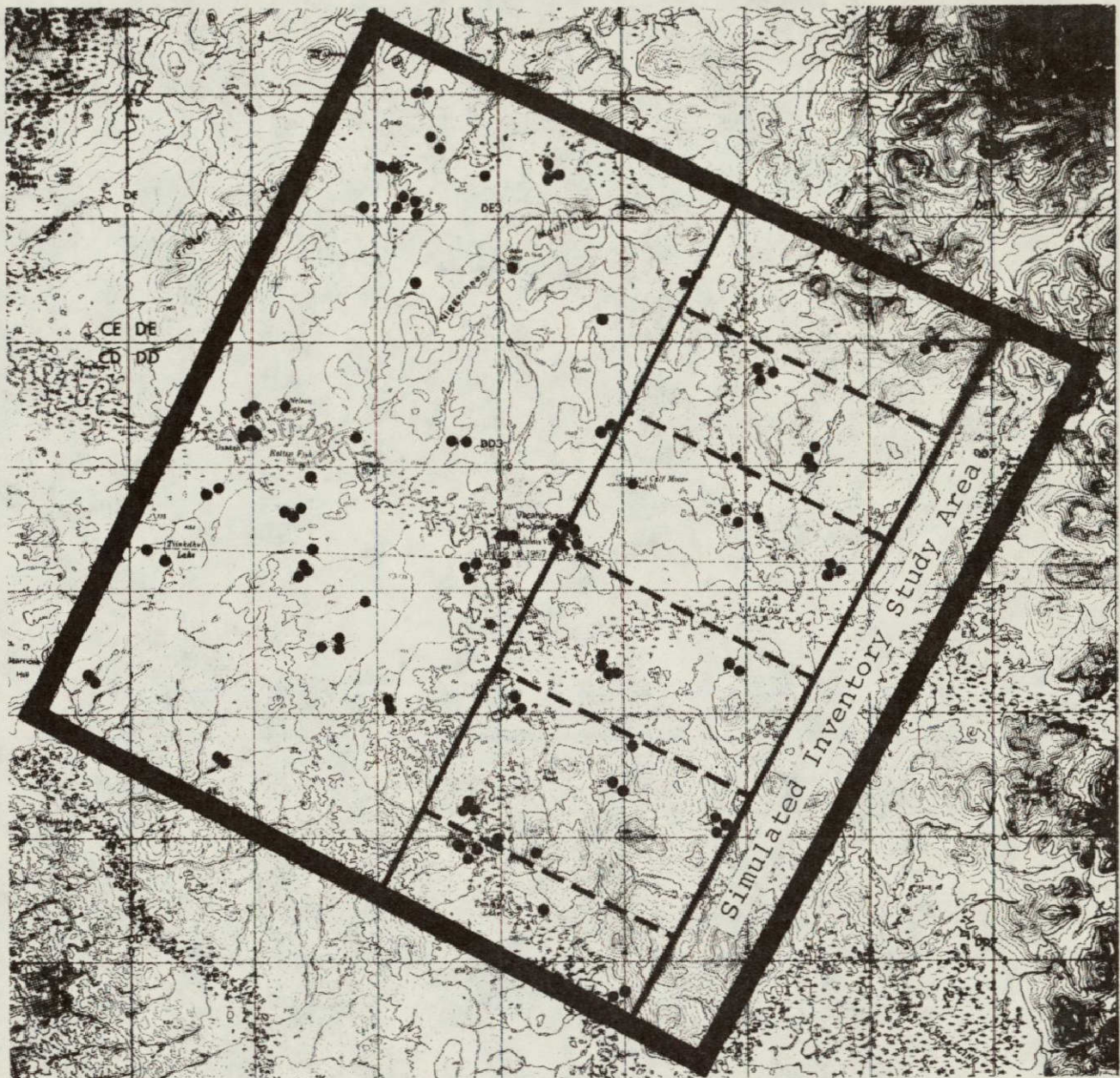


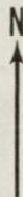
Figure 2-8.- Moist sedge and grass vegetation.

PRECEDING PAGE BLANK NOT FILMED
2-25



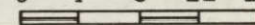
Legend:

- Training field
- Aerial route



Average scale:

0 4 8 12 16 kilometers



0 5 10 miles

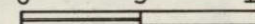


Figure 2-9.- Training fields and aerial reconnaissance route of the field survey teams.

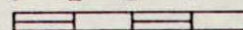


N
↑

ORIGINAL PAGE IS
OF POOR QUALITY

Average scale:

0 1 2 3 4 kilometers



0 1 2 miles

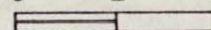
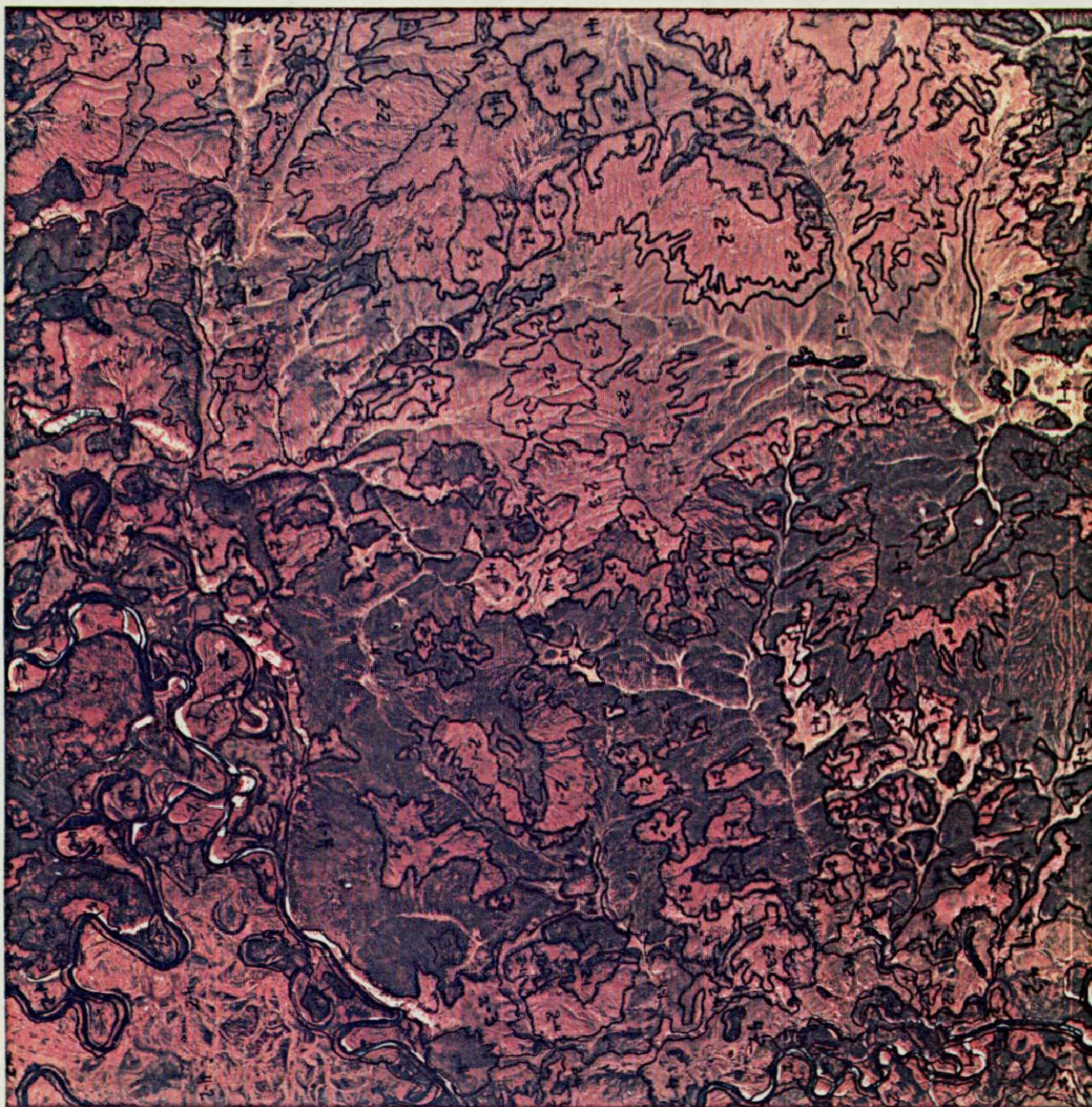


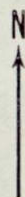
Figure 2-10.- Stereogram of a portion of the Alaska study site.

PRECEDING PAGE BLANK NOT FILMED
2-29



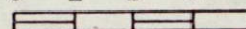
Note:

The photograph is number 183 of roll 9, Mission 345, flown on August 27, 1976. The number code on the overlay corresponds with that on table 2-2.



Average scale:

0 1 2 3 4 kilometers

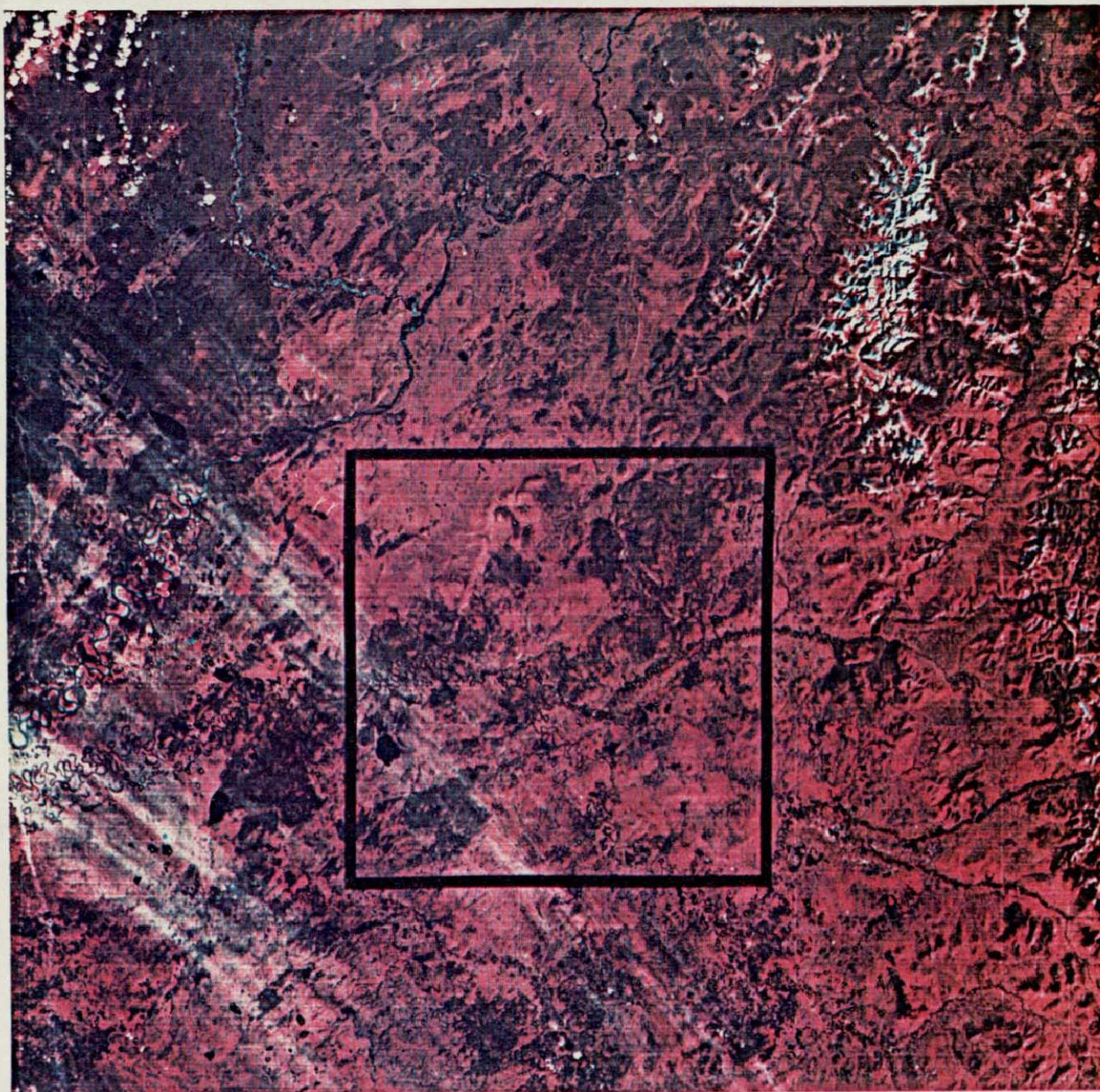


0 1 2 miles



Figure 2-11.- Color infrared aerial photograph of a portion of the Alaska study site and overlay.

PRECEDING PAGE BLANK NOT REPRODUCED



Note:

The imagery is frame number
2583-20181, dated
August 27, 1976.



Average scale:

0 10 20 30 kilometers



0 8 16 miles

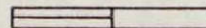
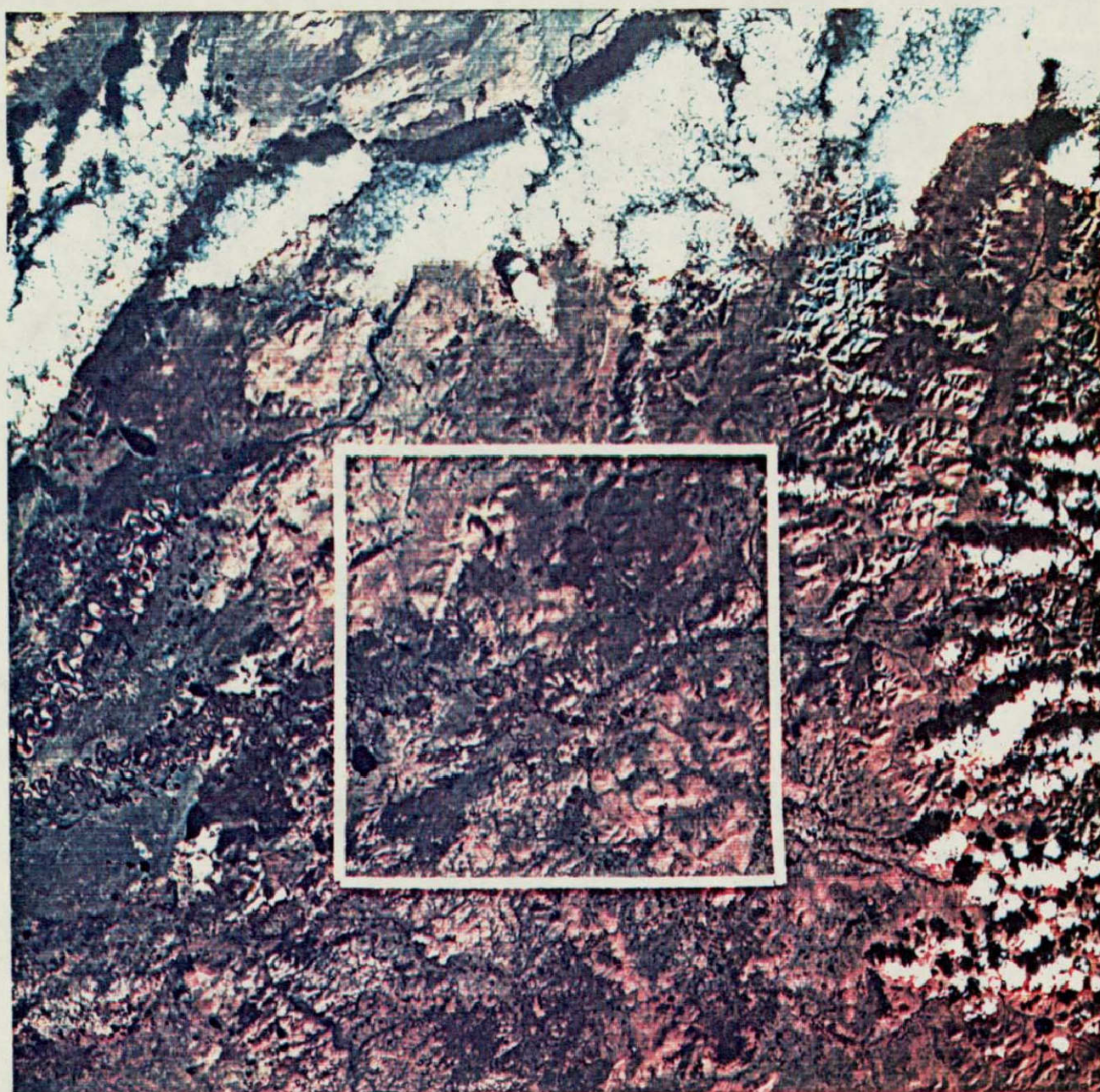


Figure 2-12.- August Landsat color composite indicating
the Alaska study site.

PRECEDING PAGE BLANK NOT FILMED



Note:

The imagery is frame number 1407-20371, dated September 3, 1973.



Average scale:

0 10 20 30 kilometers

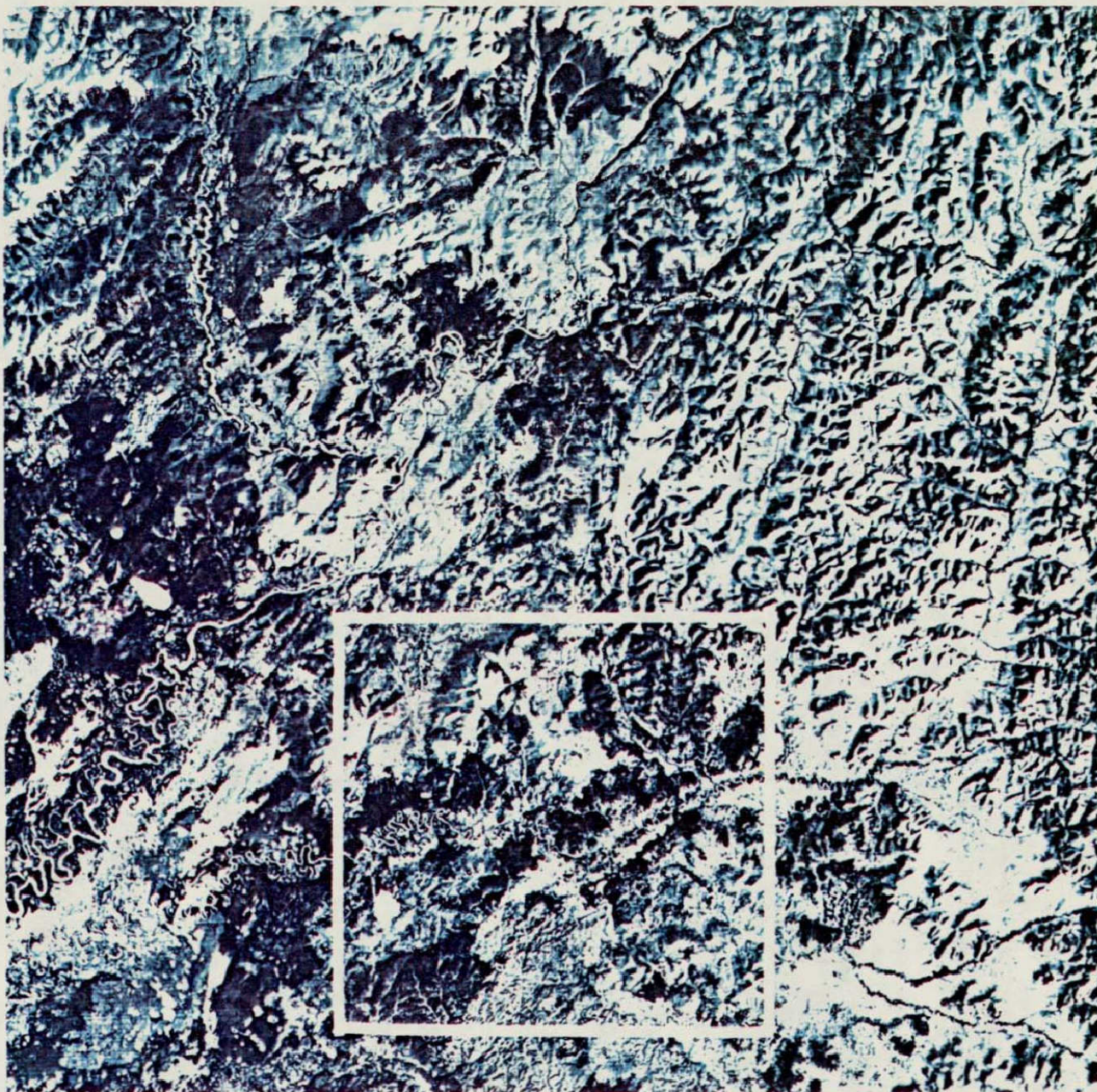


0 8 16 miles



Figure 2-13.- September Landsat color composite indicating the Alaska study site.

PRECEDING PAGE OR ANY PAGE FILMED

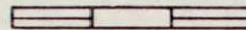


Note:

The imagery is frame number
1587-20333, dated March 2, 1974.

Average scale:

0 10 20 30 kilometers



0 8 16 miles

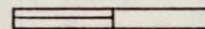


Figure 2-14.- March Landsat color composite indicating
the Alaska study site.

PRECEDING PAGE BLANK NOT FILMED

3. PREPROCESSING

The overall purpose of this task was to prepare the three Landsat data tapes for analysis on the Interactive Multispectral Image Analysis System, Model 100 (Image 100) system and to scale the output data. More specifically, the objectives were:

- a. To register three data sets image to image
- b. To register the data-to-map control points
- c. To calculate the scale factor and pixel size
- d. To locate and place training field boundaries on the data sets
- e. To film the resultant Landsat data

A detailed description of the procedures followed for this task is given in section 4.5 of reference 1. The following sections briefly summarize these procedures and describe the results achieved.

3.1 IMAGE-TO-IMAGE REGISTRATION

The September 1973 data image set was chosen as the base image, and the August 1976 and March 1974 images were registered to it. Fifty-five control points were used to register the August data set to the September one, and 63 control points were used to register the March data set to the one for September. The Earth Resources Interactive Processing System (ERIPS) was utilized to complete this task. Final evaluation of the positional accuracy with 45 points for the August/September registration showed a root-mean-square error of 1.0 pixel (80 by 80 meters or 87.2 by 87.2 yards), whereas the root-mean-square error for the March/September registration was 1.1 pixel (88 by 88 meters or 95.9 by 95.9 yards).

3.2 IMAGE-TO-GROUND REGISTRATION

Thirty-eight control points were selected to register the Landsat September image to the 1:250 000-scale Army Map Service topographic map of Black River, Alaska. Because the September date was used as a base for registration for both the March and August data sets, only the September date had to be registered to the map. A least-squares analysis was run, and control points with a sample error (ΔX) or a line error (ΔY) greater than 2.4 pixels (192 by 192 meters or 209.3 by 209.3 yards) were eliminated. Lakes and rivers were the only control points available, but these proved to be adequate. The root-mean-square line error was 0.95 pixel (76 by 76 meters or 82.8 by 82.8 yards) with a root-mean-square sample error of 0.15 pixel (12 by 12 meters or 13.1 by 13.1 yards). Coefficients of the least-squares analysis were used to calculate the rotation factor, giving a value of 0.029.

3.3 SCALE FACTOR AND PIXEL SIZE

A Landsat pixel is not square; therefore, in order to overlay a pixel on a ground map, the pixel must be made square. A square pixel was obtained by duplicating approximately every third line; for example, 350 Landsat lines were displayed as 485 lines. The size of the new pixel was calculated and used to determine area estimates. The pixels appearing on the Gould printer were square and contained 0.333 square hectometer (0.825 acre). The Jacobi calculation was used to determine the pixel size (ref. 6).

3.4 ADMINISTRATIVE BOUNDARIES

The Alaska test site has no meaningful administrative boundaries (ref. 7); the only existing boundary of any sort is the west side of the proposed Porcupine National Forest. A comparison between NFAP and Forest Service statistics cannot be made

because there are no existing statistics for this forest; therefore, boundaries on the image were not superpositioned.

3.5 TRAINING FIELD SELECTION

Training fields with only one feature of interest and a size of at least 2 square hectometers (5 acres) were selected from throughout the site. The identity of the Level II features (table 2-1) was confirmed by aerial photography and/or ground observation.

For the type separability study, training fields were distributed over the four quadrants of data.

In the simulated inventory study, training fields were selected from a strip consisting of 10 percent of the total area on the southeastern edge of the site in segments 2 and 4 of figure 2-9. This strip of land varies in topography from hilltops to a river bottom and therefore contains all the major vegetation types found within the site. The training fields were selected solely from the aerial photography without the aid of ground observation.

4. PROCESSING

This task was conducted for two primary purposes: (1) to determine the level of detail at which forest and tundra features can be differentiated through a type separability study and (2) to determine how well limited ground-truth information can be used to extend class signatures for the classification of the entire site through a simulated inventory.

The main objectives of the separability study were:

- a. To determine the cell resolution size
- b. To obtain an n-dimensional master signature
- c. To determine the training field accuracies
- d. To determine the best date based on the overall separability study accuracies
- e. To perform a Level III classification and compare the dates

The objectives of the simulated inventory included:

- a. Developing an n-dimensional signature from a predesignated 10 percent of the study site using the best date determined by the separability study
- b. Performing a classification of the entire site
- c. Producing area estimates and classification theme prints

The procedures followed are described in detail in section 5.5 of reference 1. These procedures and the results of the processing task are summarized in the following sections.

4.1 SEPARABILITY STUDY

4.1.1 SELECTION OF BANDS FOR PROCESSING THE TEMPORAL DATA

Bands 1, 2, 3, and 4 of the temporal tape represent bands 2 and 4 of the September date and bands 6 and 8 of the August date, respectively. A second temporal tape was made using the same band exchange for the September date but replacing the August bands with bands for the March date. These bands were selected to provide one band of visible data and one band of infrared data for each date; they also offered the best visual representation.

4.1.2 MASTER SIGNATURE

The master or super signature was obtained for all training fields after the n-dimensional training was completed. In the cases where pixels or classes overlapped each other, a maximum-likelihood-decision program was run to resolve and eliminate this overlap. This program allowed a weighting factor to influence the disputed pixel assignments. The *a priori* inputs were 33 for softwood, 26 for hardwood, 29 for tundra, and 3 for water. These numbers were derived from an estimation of the percentage of the entire scene which a feature occupies.

4.1.3 TRAINING FIELD ACCURACIES

Level II training field accuracies were obtained by dividing the number of correctly classified pixels for a particular signature by the total number of pixels within the training fields of that signature. This procedure was followed for each class. The overall accuracy was obtained by summing all correctly classified pixels for each class (i.e., softwood, hardwood, tundra, and water) and dividing them by the total number of pixels from all four quadrants. Table 4-1 shows the training field accuracies (in percents) for each data set.

A Level III separability study was conducted when the softwood, hardwood, and water accuracies exceeded 90 percent and the tundra accuracy exceeded 80 percent (ref. 1).

4.1.4 LEVEL III CLASSIFICATION

Four Level III classes were defined, and an attempt was made to classify the entire site according to these classes. Softwood (white and black spruce) and tundra training field boundaries used for the Level II separability study were again placed on the data. The softwood Level II training fields were divided into either sparse spruce (≤ 50 -percent crown closure) or dense spruce (> 50 -percent crown closure), and the Level II tundra training fields were divided into either grass or brush. The information required for the Level III training fields was gathered on the ground. Some additional training fields were required, and aerial photography was used as the ground-truth data for these.

The September/August temporal data set was used as a data base to classify the four Level III features. In addition, the partly snow-covered March data were processed with the hope that the amount of exposed spruce crown would be enhanced by snow. On this particular scene, there is more snow cover, and the spruce becomes more apparent. Therefore, the March date allows for an easier interpretation of density within the spruce stands because of the greater contrast and less spectral confusion. The March date was not expected to indicate differences in the Level III grass and brush classifications.

The training field accuracies for the Level III training fields on the September/August temporal data, the March data, and the September/March temporal data are given in table 4-2.

4.2 SIMULATED INVENTORY STUDY

The simulated inventory study was conducted to investigate how accurately the study site can be classified using signatures from training fields selected from a limited area (10 percent of the site) and using aerial photographs to choose the training fields without the aid of ground observation. The September/August temporal data set was used for the inventory because its overall type separability accuracy of 99.5 percent was higher than for September or August. Signatures were developed from these fields, and the entire study site was classified.

Training field accuracies were calculated to be 100 percent for softwood, 98 percent for hardwood, 99 percent for tundra, and 96 percent for water (table 4-1).

Table 4-3 shows the area classified on each date, including the inventory of each Level II feature.

TABLE 4-1.- SUMMARY OF TRAINING FIELD CLASSIFICATION
ACCURACIES FOR THE SEPARABILITY AND
INVENTORY STUDIES

Level II feature	Separability study			Temporal inventory, percent
	September, percent	August, percent	Temporal, percent	
Softwood	99.0	99.5	99.9	100
Hardwood	98.0	95.0	99.0	98
Tundra	97.0	97.0	99.0	99
Water	99.5	99.0	99.9	96
Overall accuracy	98.4	97.6	99.5	98

TABLE 4-2.- SUMMARY OF TRAINING FIELD CLASSIFICATION
ACCURACY FOR THE LEVEL III
SEPARABILITY STUDY

Feature	September/August temporal, percent	March, percent	September/March temporal, percent
Sparse spruce	92	81	91
Dense spruce	66	50	32
Grass tundra	99.5	82	89
Brush tundra	44	88	74

TABLE 4-3.- SUMMARY OF CLASSIFICATION RESULTS, FORT YUKON, ALASKA

Class	Master signature			
	August separability	September separability	Temporal separability	Temporal inventory
Softwood:				
Square hectometers	127 619.1	103 323.7	94 872.0	85 618.9
Acres	315 219.3	255 209.6	234 333.8	211 478.8
Hardwood:				
Square hectometers	40 490.4	59 391.0	66 125.9	37 964.0
Acres	100 011.4	146 695.7	163 331.0	93 771.2
Tundra:				
Square hectometers	78 800.5	133 960.3	90 260.3	84 829.4
Acres	194 637.3	330 881.9	222 943.0	209 528.6
Water:				
Square hectometers	6 259.0	4 909.0	3 090.6	3 311.4
Acres	15 459.7	12 127.5	7 633.7	8 179.1
Other:				
Square hectometers	54 070.6	5 654.8	52 890.9	85 515.9
Acres	133 554.3	13 967.0	130 640.5	235 924.3

5. POSTPROCESSING

The site classification from the September/August temporal inventory data (see section 4) and the signatures for 10 percent of the area were used to produce classification maps at a scale of 1:126 000 to be analyzed during the evaluation task.

The objectives of the postprocessing task were:

- a. To refine the classification results from the processing task by reassigning parcels of land smaller than the basic mapping units into the larger surrounding class [The basic mapping units were 4 square hectometers (10 acres) for forest and tundra, 16.2 square hectometers (40 acres) for census water, and 0.4 square hectometer (1 acre) for noncensus water.]
- b. To produce alphanumeric classification printouts of the site containing twenty-five 50- by 50-pixel primary sampling units (PSU's) to be used in the evaluation task
- c. To produce a color-coded map of the simulated inventory temporal classification data as a final product

The procedures followed for the postprocessing task are given in section 6.3 of reference 1. These procedures and the results of the task are summarized in the following sections.

5.1 PASSIVE MICROWAVE IMAGING SYSTEM/DATA ANALYSIS SYSTEM FALSE-COLOR FILMING

Two sets of color positive transparencies were made on the Passive Microwave Imaging System/Data Analysis System (PMIS/DAS). Each set consisted of one frame, representing a fourth of the study site. The data from the inventory classification tape were used for one set (fig. 5-1), and the other set was made

from the September color-composite set (fig. 5-2). The latter set of transparencies was used as an aid for PSU location during the evaluation task.

5.2 UNIVAC 1110

The data were processed with the GETMIX/CLEAN program (ref. 8) on the Univac 1110 to eliminate classified areas of 4 square hectometers (10 acres) or less and to reassign these areas to the surrounding class. The program also distinguished census water from noncensus water, using the 16.2-square-hectometer (40-acre) requirement (fig. 5-3). The Univac 1110 was also used to combine the four separate segments into a single data tape.

During the GETMIX/CLEAN program run, the quality of the tapes was checked periodically with the PMIS/DAS. All of the tapes used were of good quality.

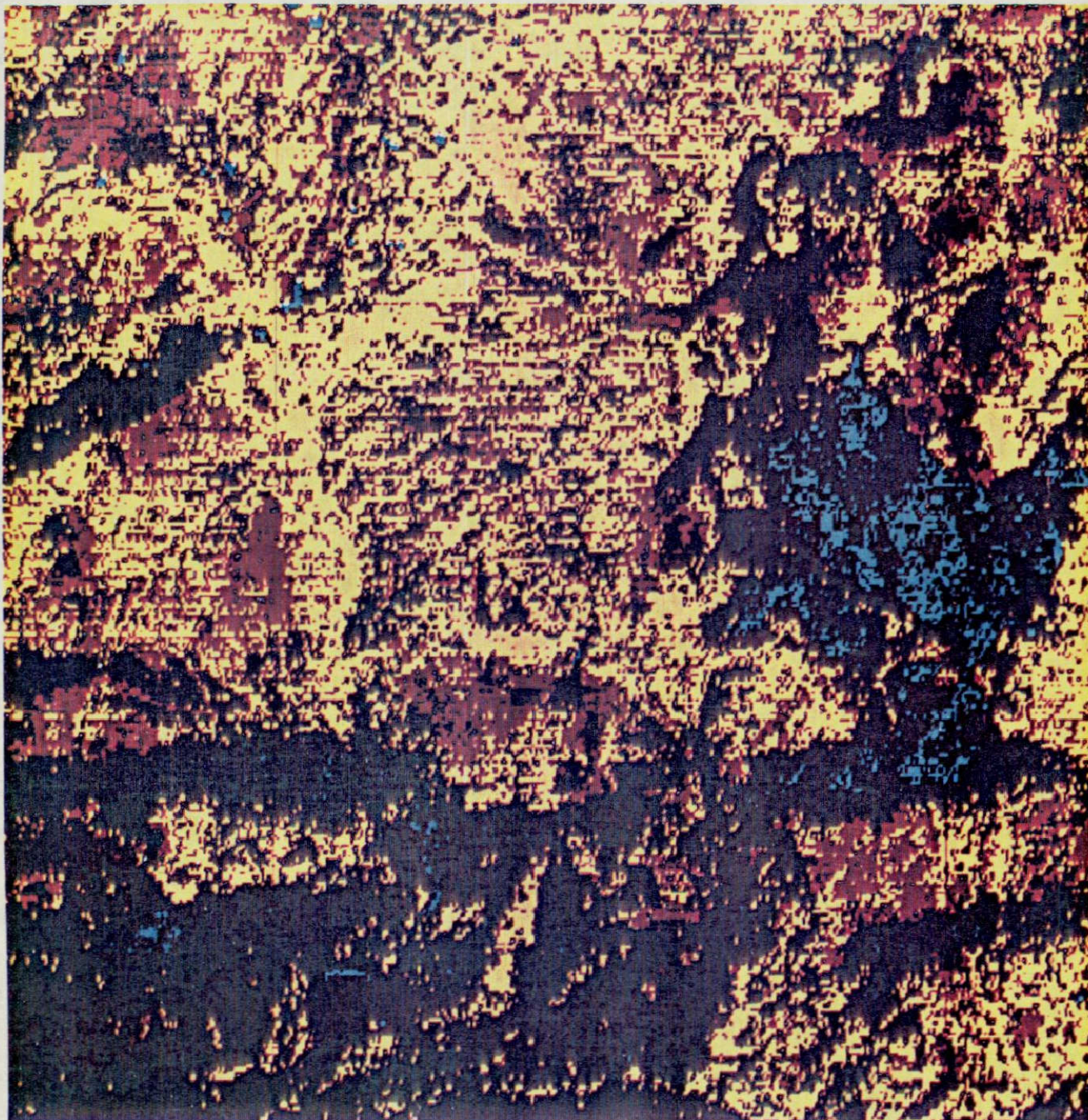
5.3 PSU LOCATION

The classification tapes were utilized to produce alphanumeric theme prints. The PSU's, each 50 by 50 pixels in size, were randomly located on the printout, the DAS transparencies, and the aerial photographs. The PSU's were randomly selected from the 970- by 970-pixel study site. Ten secondary sampling units (SSU's) were then placed randomly within the PSU (fig. 5-4). Each of the SSU's was 2 by 2 pixels in size. The locations of the 25 PSU's used for the evaluation are shown in figure 5-5.

5.4 FINAL OUTPUT PRODUCT

The merged tape containing the classification of all four segments was taken to a private subcontractor where a color-coded classification map of softwood, hardwood, tundra, and other was prepared. The map was produced by a direct image process: a laser was used to transfer the image directly from

the computer tape to a light-sensitive plate; then the plate was processed with Cromalin dust to make the final print. The cost was relatively inexpensive and turnaround time was approximately 3 weeks. Figure 5-6 is a copy of the final classification map. .



Legend:

Green — Softwood
Red — Hardwood
Yellow — Tundra
Blue — Water
Black — Other

Figure 5-1.- Inventory classification of Level II features
of quadrant 1 of the Alaska study site.

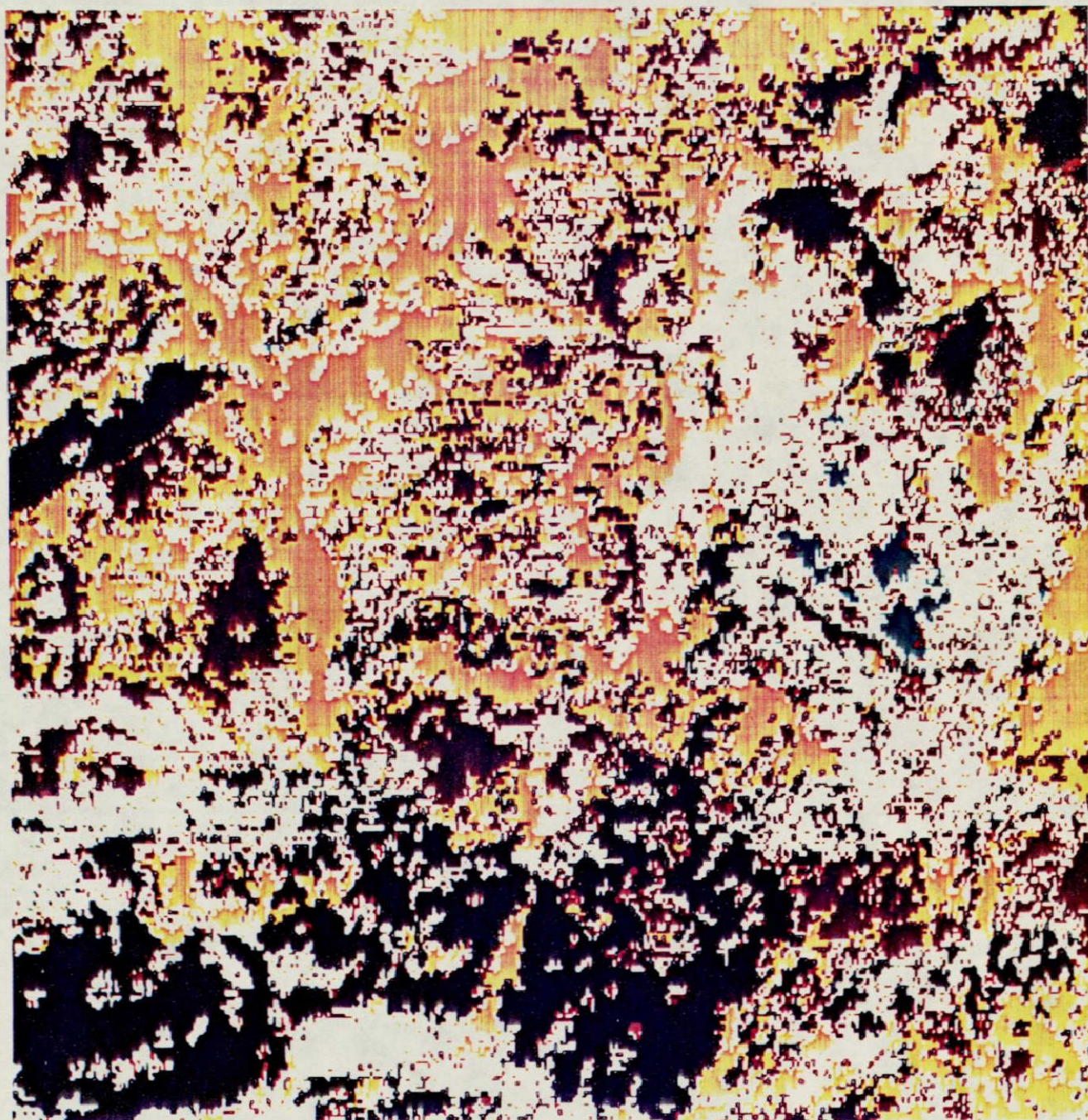
PRECEDING PAGE BLANK NOT FILMED



ORIGINAL PAGE IS
OF POOR QUALITY

Figure 5-2.- Landsat raw data from September imagery of
quadrant 1 of the Alaska study site.

PRECEDING PAGE BLACK NOT FILMED
5-7



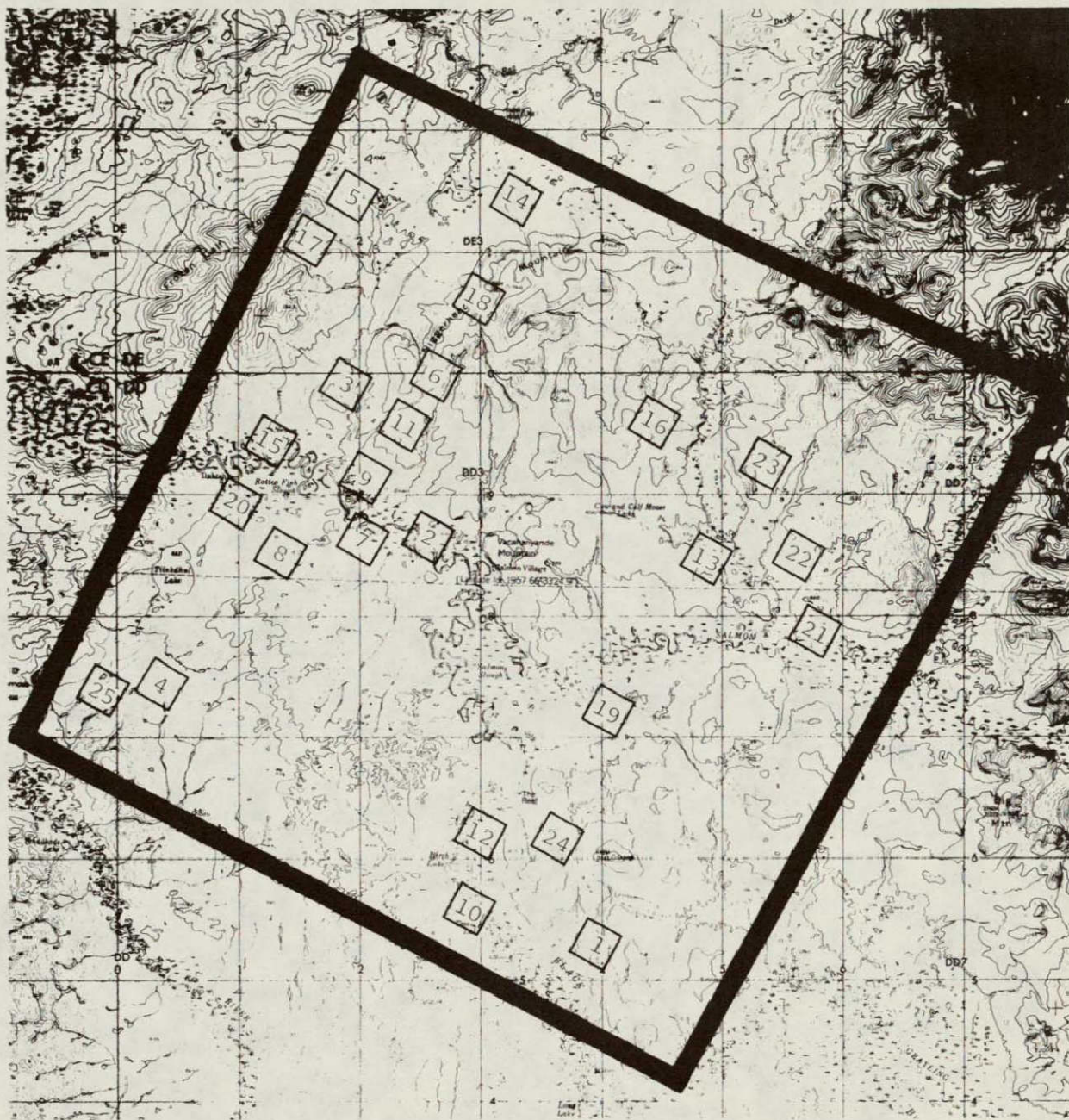
Legend:

Green — Softwood
 Red — Hardwood
 Yellow — Tundra
 Blue — Water
 Black — Other

ORIGINAL PAGE IS
 OF POOR QUALITY

Figure 5-3.- Inventory classification of Level II features of quadrant 1 of the Alaska study site after running GETMIX/CLEAN.

PRECEDING PAGE BLANK NOT FILMED

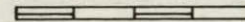


ORIGINAL PAGE IS
OF POOR QUALITY



Average scale:

0 4 8 12 16 kilometers



0 5 10 miles

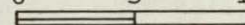
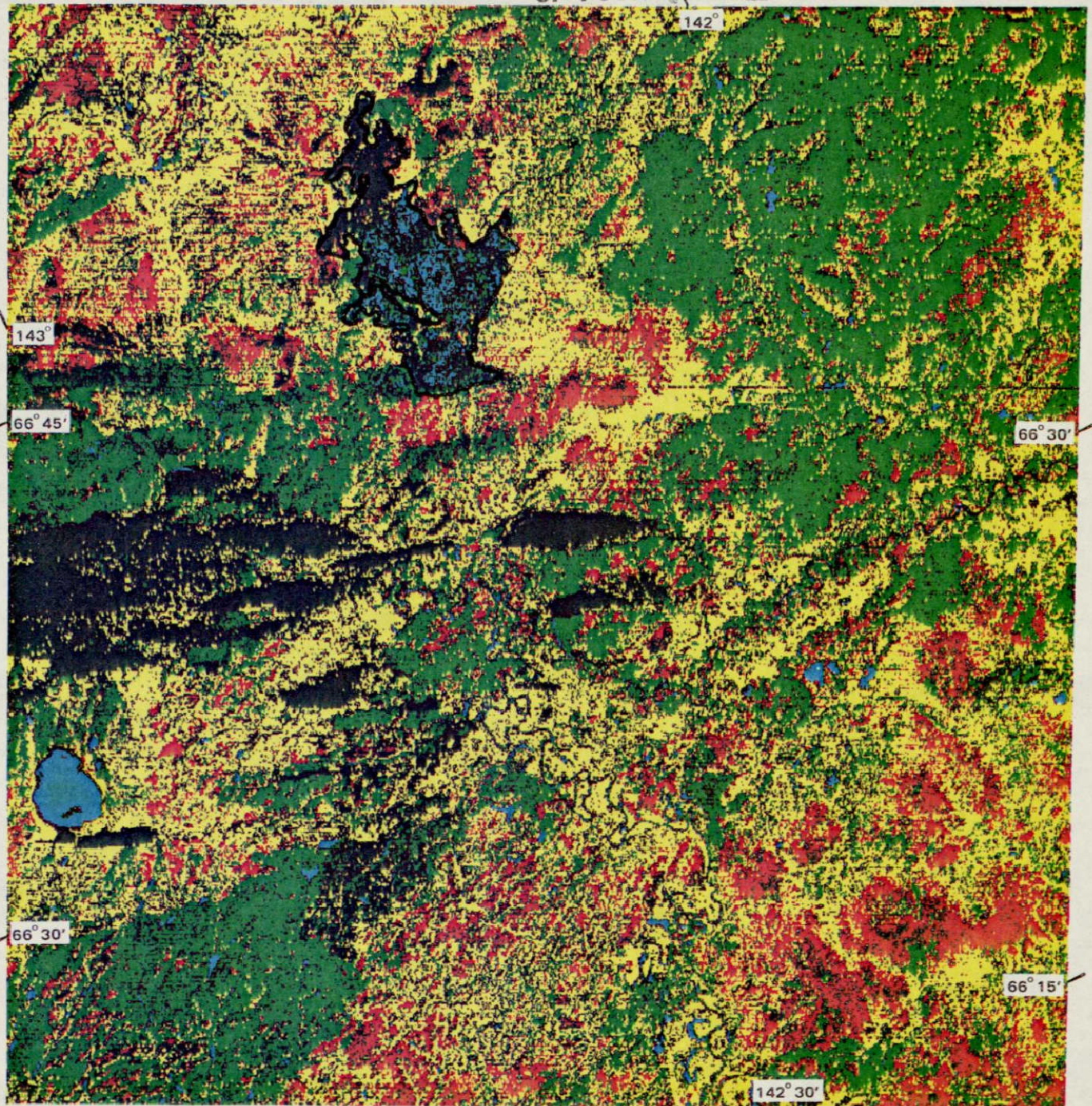
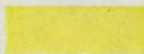


Figure 5-5.- Locations of the 25 PSU's in the site.

PRECEDING PAGE BLANK NOT FILMED

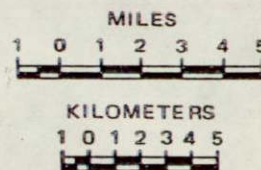


LEGEND

SOFTWOOD	
HARDWOOD	
TUNDRA	
WATER	
OTHER	

CLASSIFICATION FROM LANDSAT

1407 - 20371 SEPTEMBER 1973
2583 - 20181 AUGUST 1976



NOTE: WATER AND CHARRED LAND HAVE SIMILAR SIGNATURES, AND CONFUSION MAY EXIST AS SEEN IN THE OUTLINED AREAS.



Analysis by:
Lockheed Electronics Co., Inc.
Forestry Applications Section
July 1978
Contract NAS 9-15200

Figure 5-6.- Final classification map.

6. EVALUATION

The purpose of this task was to evaluate the accuracy of the classification map produced from the processing task. The primary objectives were to determine;

- a. The overall map percent of correct classification (PCC)
- b. The confidence interval for the PCC
- c. The proportion of each class
- d. The proportion error for each class
- e. The improvement in the precision of class area estimates by the regression calculation
- f. If class proportion errors can be removed by applying a transformation derived from the regression of aerial photographs and the simulated inventory sample data

The site classification from the September/August temporal inventory data and signatures from 10 percent of the area were evaluated. A statistical sampling technique of the classification was used to quantify the overall map accuracy, the proportion estimation, and the errors in the proportion estimation. Twenty-five 50- by 50-pixel PSU's, each containing ten 2- by 2-pixel SSU's, were randomly selected from the classification map. These PSU's were then evaluated against interpreted aerial photographs which, for this study, were assumed to represent ground truth. The procedures followed are described in detail in section 7.3 of reference 1.

The results of the evaluation task are presented in tables 6-1 through 6-3. Table 6-1 contains a statistical estimate of the overall PCC and its confidence interval for 25 PSU's. Table 6-2 denotes the average photointerpretation class proportion (p); the average ADP inventory class proportion ($\hat{p}$); the average

error (B), or deviation, between the two; and the error confidence interval. Regression estimates of wall-to-wall class proportion and associated precision may be found in table 6-3.

TABLE 6-1.- ESTIMATED PCC AND CONFIDENCE INTERVAL AT THE
90-PERCENT CONFIDENCE LEVEL FOR 25 PSU'S

Inventory sample size	PCC	Half-confidence interval, $\Delta_{.9}$	PCC $\pm \Delta_{.9}$
25 PSU's	72.4%	5.9%	66.5% to 78.3%

TABLE 6-2.- AVERAGE ERRORS (B) BETWEEN CLASS PROPORTION ESTIMATES
FROM AERIAL PHOTOINTERPRETATION AND LANDSAT ADP INVENTORY
CLASSIFICATION OF FORT YUKON, ALASKA, TEST SITE

Class	Inventory 25 PSU's ^a			
	Photointerpretation proportion, p	ADP class proportion, $\hat{p}$	Average error, B	Confidence interval, $B \pm \Delta_{.9}$
Softwood	0.338	0.358	-0.020	(-0.052, 0.012)
Hardwood	0.142	0.102	0.040	(0.019, 0.061)
Tundra	0.276	0.268	0.008	(-0.021, 0.037)
Water	0.008	0.005	0.003	(-0.002, 0.008)
Other	0.236	0.267	-0.031	(-0.055, -0.007)

^aThese 25 PSU's were randomly located in the site.

TABLE 6-3.- REGRESSION ESTIMATES OF PROPORTION AND ASSOCIATED PRECISION

Class	Simulated inventory proportions, p_{inv}	Regression equation	Regression estimates of proportions, $\langle p/p_{inv} \rangle^a$	Coefficient of determination, r^2	Variance of the estimate, $s_{\langle}^2$	Half-confidence interval, $\Delta_{.9}$	Percent relative variation, $100\Delta/\langle \rangle$
Softwood	0.2794	$\langle p \rangle = 0.89p_{inv} + 0.019$	0.2675	0.90	0.00343	0.031695	11.9
Hardwood	0.1243	$\langle p \rangle = 0.88p_{inv} + 0.052$	0.1612	0.83	0.000148	0.020795	12.9
Tundra	0.2767	$\langle p \rangle = 0.94p_{inv} + 0.023$	0.2846	0.83	0.000308	0.030045	10.6
Water	0.0108	$\langle p \rangle = 1.59p_{inv} + 0.0004$	0.03283	0.64	0.000011	0.005618	32.1

Symbol definition:

$$\langle p \rangle = \langle p/p_{inv} \rangle$$

^aThe conditional expectation of p , given p_{inv} .

7. DIRECT RESOURCE UTILIZATION

Certain resources were required for the study but were not financed through the standard overhead. These included (1) site data, such as the Landsat imagery, the aerial photographs, and ancillary information; (2) manpower; and (3) machine and equipment time.

Throughout the study, hourly records were kept on man-hours and machine time, including the costs of transportation, food, and lodging for the five team members from Houston who visited Site VI. These are listed in table 7-1.

Table 7-2 shows the breakdown of the hourly costs for machine time and manpower. A comparison of the total costs with the total land area shows that the direct costs amounted to 16.7 cents per square hectometer (7 cents per acre).

Certain incidental costs, such as the cost of eight color-composite Landsat frames, the Landsat scenes in the form of computer-compatible tapes, and the color infrared aerial photographs from Mission 345 (flown in August 1976) are not itemized in this report.

Work performed at future sites and in a production mode would be considerably less expensive because the analysts would be familiar with the site and system characteristics. The cost analysis would still fluctuate because of the increased machine and labor costs resulting from inflation, but this could be overcome on the projected cost estimates by applying a percentage factor to the basic costs.

TABLE 7-1.- RESOURCES UTILIZED FOR SITE PROCESSING

Task	Man-hours	Actual machine hours				
		ERIPS registration	Image 100 interactive analysis	PMIS/DAS image composition	Dell Foster digitizing	Univac product merge and cleanup
Preliminary image analysis	84					
Site analysis (including trip)	480					
Preprocessing	183	20	33		8	
Processing	129		41	2		
Postprocessing	102		6	6	15	3.5
Evaluation	216					
Reporting	450					
Total	1644	20	80	8	23	3.5

ORIGINAL PAGE IS
OF POOR QUALITY

TABLE 7-2.- DIRECT COSTS FOR MACHINE TIME
AND MAN-HOURS

<u>Item</u>	<u>Cost per hour</u>	<u>Hours</u>	<u>Total cost</u>
System:			
Image 100	\$300	80	\$24 000
ERIPS	300	20	6 000
Univac 1110	300	3.5	1 050
PMIS/DAS	100	8	800
Dell Foster	15	23	<u>345</u>
Total computer cost			<u>\$32 195</u>
Man-hours:			
Salary	\$8.75 ^a	1644	\$14 385
Overhead	3.68 ^a	1644	<u>6 050</u>
Total man-hour cost			<u>\$20 435</u>
Total direct cost ^b			<u>\$52 630</u>

^aAn estimated average rate for government contract services; supplied by an informal government source.

^bAn average cost of 16.7 cents per square hectometer (7 cents per acre).

8. ANALYSIS OF RESULTS

In this section, the results of the preprocessing, processing, and postprocessing tasks are analyzed and evaluated.

Figure 8-1 illustrates the proportion of the total area covered by the classifications from inventory sample estimates, photograph sample estimates, and regression estimates. In figures 8-2 through 8-5, the results of all the proportion estimates obtained during this site study are presented graphically. These estimates are described according to their line numbers in the figures, as follows:

Line number	Description	Use
1	Wall-to-wall separability proportion estimates of the given class for the three dates and the ADP simulated inventory wall-to-wall estimate	Visual comparison of the three wall-to-wall separability estimates and the simulated inventory wall-to-wall estimate
2	ADP simulated inventory sample estimate and its 90-percent confidence interval	Comparison of the results of the simulated inventory sample estimate with both the simulated inventory wall-to-wall estimate and the separability wall-to-wall estimate of the same date; comparison of the position of the line 1 elements with the line 2 confidence interval

Line number	Description	Use
3	Aerial photograph sample estimate and its 90-percent confidence interval	Comparison of the results of the aerial photograph sampled estimate with the elements of lines 1 and 2; visual representation of its confidence interval; representation of the regression transformation between the line 2 and line 3 sample estimates by an arrow labeled R
4	ADP simulated inventory wall-to-wall estimate	Application of the regression transformation (R) to the inventory proportion
5	Regression estimate, ² its 90-percent confidence interval, and the corresponding wall-to-wall separability estimate	The <i>a priori</i> expected regression transformation, based on the assumed maximum information status of the separability wall-to wall estimate, represented by a dashed-line arrow between the simulated inventory wall-to-wall estimate (line 4) and the separability wall-to-wall estimate for the same date (line 5)

8.1 SOFTWOOD ANALYSIS

Line 1 of figure 8-2 displays the separability and inventory wall-to-wall proportion estimates for softwood, ranging from 0.278 to

²The application of the regression transformation (R) to the simulated inventory wall-to-wall estimate gives the regression estimate, which is the conditional estimate of the mean of all aerial photograph sample estimates, given the simulated inventory wall-to-wall proportion.

0.415 overall. These show less agreement than expected between the August 1976 and September 1973 separability proportions with temporal separability in the near vicinity. The temporal inventory and temporal separability estimates are fairly close (0.278 versus 0.309), as expected. However, the temporal inventory is at the lower end of the range of estimates. The reason for the wide range of estimates is not immediately apparent; falling hardwood leaves, decreased Sun angle, increased ground moisture, and other factors are not easily integrated into the cause-effect relationship.

Line 2 of figure 8-2 gives the temporal inventory sample estimate for softwood and its 90-percent confidence interval (0.358 ± 0.107 or ± 29.9 percent relative). All line 1 wall-to-wall estimates fall within this confidence interval, which is a reasonable expectation.

Line 3 contains the softwood sample estimate from photointerpretation with its 90-percent confidence interval (0.338 ± 0.101 or ± 29.8 percent relative). This sample estimate compares well with the temporal inventory sample estimate, as expected, since inventory SSU proportions were correlated with the photograph SSU proportions during the multiposition search process (ref. 1). The regression transformation (R), established between the data of lines 2 and 3, is applied to the temporal inventory wall-to-wall estimate repeated in line 4 to obtain the regression estimate of line 5 and its 90-percent confidence interval (0.268 ± 0.032 or ± 11.9 percent relative). The regression transformation reduces the confidence interval to approximately one-third of that provided by the inventory sample alone. Significantly, however, it fails to include the temporal separability wall-to-wall proportion estimate. This separability estimate, which results from spectral signatures selected from

training fields verified by on-the-ground examination, photo-interpretation, and maximum PCC qualification, is considered to be the "maximum information estimate." For softwood, the regression transformation shifts the temporal inventory estimate away from the temporal separability estimate. In figure 8-2, the dashed-line arrow between lines 4 and 5 represents the expected or "hoped for" regression transformation.

Inventory and photograph sample data for the softwood proportions are listed in table 8-1.

8.2 HARDWOOD ANALYSIS

An analysis of the hardwood data in figure 8-3 shows much the same situation in line 1 as in the softwood analysis. One notable fact is that the temporal inventory wall-to-wall proportion estimate is at the opposite end of the range from the temporal separability wall-to-wall proportion estimate (i.e., 0.124 versus 0.215). This may be an indication that the restricted inventory training field area is not representative of hardwood.

Line 2 shows the temporal inventory sample estimate and its 90-percent confidence interval (0.102 ± 0.054 or ± 52.9 percent relative). It is in good agreement with the wall-to-wall inventory estimate; however, the confidence interval contains neither the September nor the temporal separability estimates, another indication of the nonrepresentation of the inventory training field area for hardwood.

In line 3, the photograph sample estimate and its 90-percent confidence interval (0.142 ± 0.052 or ± 36.6 percent relative), although correlated with the inventory sample estimate, are shifted toward the separability estimates. The regression transformation relating the data for lines 2 and 3 indicates that

the consistent error component (intercept $b = 0.052$ versus slope $m = 0.88$) is slightly more dominant, further supporting the nonrepresentation of the inventory training area for hardwood.

The application of the regression transformation to the temporal inventory wall-to-wall estimate illustrated in line 4 obtains the regression estimate and its 90-percent confidence interval on line 5 (0.161 ± 0.021 or ± 12.9 percent relative). Although the regression transformation produces an estimate closer to the temporal separability wall-to-wall estimate, it falls short and the separability estimate is not included in the resulting confidence interval.

Inventory and photograph sample data for the hardwood proportions are listed in table 8-2.

8.3 TUNDRA ANALYSIS

The tundra estimates (fig. 8-4) are closely grouped except for the wide separation of the September separability wall-to-wall estimate in line 1. These estimates are contained within the 90-percent confidence interval and are in agreement with the temporal inventory sample estimate (0.268 ± 0.07 or ± 25.9 percent relative).

The photograph sample estimate and its 90-percent confidence interval (0.276 ± 0.072 or ± 26.1 percent relative) support a near-identity regression transformation. Applying this transformation to the temporal inventory wall-to-wall proportion estimate yields the regression estimate and its 90-percent confidence interval (0.285 ± 0.030 or ± 10.6 percent relative), illustrated in line 5. This confidence interval contains the desired temporal separability estimate.

Inventory and photograph sample data for the tundra proportions are given in table 8-3.

8.4 WATER ANALYSIS

The separability and temporal estimates of water (fig. 8-5, line 1) are in good agreement. In line 2, the temporal inventory sample estimate is 0.005 ± 0.004 or ± 85.8 percent relative. This estimate agrees fairly well with the temporal inventory and separability estimates contained within the 90-percent confidence interval. On line 3, the photograph sample estimate (0.0084 ± 0.0085 or ± 100.1 percent relative) differs by a factor of 2 from the inventory sample estimate.

An examination of the resulting regression coefficient shows that the relationship between the two estimates is mostly proportional (slope $m = 1.57$ versus intercept $b = 0.0004$). This indicates that approximately 37 percent of the water observed in the photograph sample is not classified as water in the inventory sample.

The application of the regression transformation to the temporal inventory wall-to-wall proportion estimate yields line 5, the regression estimate and its 90-percent confidence interval (0.018 ± 0.006 or ± 32.10 percent relative). This regression estimate is away from the temporal separability proportion estimate for water (0.01).

Inventory and photograph sample data for water proportions are listed in table 8-4.

8.5 LEVEL I REPRESENTATION

A further means of comparison, at a Level I representation, is provided in table 8-5. The Level I forest estimates are obtained

by adding the hardwood and softwood proportions together. The consistent close agreement between the three separability estimates for forest (0.547, 0.529, and 0.524) strengthens confidence in the accuracy of these estimates, particularly in view of the large trade-off between tundra and other (unclassified) in the September separability study. The loss of some 12 percentage points in the Level I inventory estimate for forest (0.402) is assumed to be caused primarily by the loss in hardwood (from 0.215 to 0.124). Softwood (0.278) explains 3 percentage points, while tundra and water remain relatively stable. The application of the softwood and hardwood regression transformations fails to recover more than 3 percentage points for forest. The regression transformation introduces a further loss of softwood.

11 11 11
YUUAUQ 40 11 11

TABLE 8-1.- INVENTORY AND PHOTOGRAPH SAMPLE DATA FOR
SOFTWOOD PROPORTIONS

Statistical function, x	Simulated inventory estimate from 25 samples, $\hat{p}$	Aerial photointerpretation estimate from 25 samples, p	Regression estimate from simulated inventory, p_{inv}
$\bar{x}$	0.358	0.3376	0.2794
s^2	.097913	.086277	
$\frac{s^2}{\bar{x}}$	.003917	.003451	
$s_{\bar{x}}$	.062582	.058746	
$\Delta_{.9}$	.107078	.100514	
$100\Delta/\bar{x}$	29.91%	29.77%	
r^2		.90122	
m		.89119	
b		.01855	
$\langle p/p_{inv} \rangle$			.2675
$s_{<}^2$			.00343
$s_{<}$			.018524
$\Delta_{.9}$			.031695
$100\Delta/<$			11.85%

Symbol definitions:

$\bar{x}$ = mean of the x_i
 s^2 = variance of the x_i
 $\frac{s^2}{\bar{x}}$ = variance of the mean
 $s_{\bar{x}}$ = standard deviation of the mean
 $\Delta_{.9}$ = half-confidence interval with confidence coefficient equal to 0.9
 $100\Delta/\bar{x}$ = relative variation of x in percent
 r^2 = coefficient of determination (fraction of sum squares about the mean that is removed by the regression)
 m = slope of regression line
 b = intercept of regression lines (on y-axis)
 $\langle p/p_{inv} \rangle$ = regression estimate of p ; i.e., the conditional estimate of the mean photograph proportion, given the inventory sample mean
 $s_{<}^2$ = variance of $\langle p/p_{inv} \rangle$
 $s_{<}$ = corresponding standard deviation
 $100\Delta/<$ = relative variation of regression estimate in percent at confidence coefficient equal to 0.9

ORIGINAL PAGE IS
OF POOR QUALITY

TABLE 8-2.- INVENTORY AND PHOTOGRAPH SAMPLE DATA FOR
HARDWOOD PROPORTIONS

Statistical function, x	Simulated inventory estimate from 25 samples, $\hat{p}$	Aerial photointerpretation estimate from 25 samples, p	Regression estimate from simulated inventory, p_{inv}
$\bar{x}$	0.102	0.1416	0.1243
s^2	.024892	.022872	
$s_{\bar{x}}^2$	.000996	.000915	
$s_{\bar{x}}$	.031554	.030247	
$\Delta_{.9}$	.053989	.051753	
$100\Delta/\bar{x}$	52.93%	36.55%	
r^2		.84183	
m		.87951	
b		.05189	
$\langle p/p_{inv} \rangle$			.1612
$s_{<}^2$			.000148
$s_{<}$			.012154
$\Delta_{.9}$			.020795
$100\Delta/<$			12.90%

Symbol definitions:

$\bar{x}$ = mean of the x_i
 s^2 = variance of the x_i
 $s_{\bar{x}}^2$ = variance of the mean
 $s_{\bar{x}}$ = standard deviation of the mean
 $\Delta_{.9}$ = half-confidence interval with confidence coefficient equal to 0.9
 $100\Delta/\bar{x}$ = relative variation of x in percent
 r^2 = coefficient of determination (fraction of sum squares about the mean that is removed by the regression)
m = slope of regression line
b = intercept of regression lines (on y-axis)
 $\langle p/p_{inv} \rangle$ = regression estimate of p; i.e., the conditional estimate of the mean photograph proportion, given the inventory sample mean
 $s_{<}^2$ = variance of $\langle p/p_{inv} \rangle$
 $s_{<}$ = corresponding standard deviation
 $100\Delta/<$ = relative variation of regression estimate in percent at confidence coefficient equal to 0.9

TABLE 8-3.- INVENTORY AND PHOTOGRAPH SAMPLE DATA FOR
TUNDRA PROPORTIONS

Statistical function, x	Simulated inventory estimate from 25 samples, $\hat{p}$	Aerial photointerpretation estimate from 25 samples, p	Regression estimate from simulated inventory, p_{inv}
$\bar{x}$	0.268	0.2764	0.2767
s^2	.041183	.044378	
$s_{\bar{x}}^2$	.001647	.001715	
$s_{\bar{x}}$	.0040587	.042132	
$\Delta_{.9}$	.069445	.072088	
$100\Delta/\bar{x}$	25.91%	26.08%	
r^2		.82662	
m		.94431	
b		.02332	
$\langle p/p_{inv} \rangle$			.2846
$s_{<>}^2$			.000308
$s_{<>}$			.017560
$\Delta_{.9}$			.030045
$100\Delta/<>$			10.55%

Symbol definitions:

$\bar{x}$ = mean of the x_i
 s^2 = variance of the x_i
 $s_{\bar{x}}^2$ = variance of the mean
 $s_{\bar{x}}$ = standard deviation of the mean
 $\Delta_{.9}$ = half-confidence interval with confidence coefficient equal to 0.9
 $100\Delta/\bar{x}$ = relative variation of x in percent
 r^2 = coefficient of determination (fraction of sum squares about the mean that is removed by the regression)
 m = slope of regression line
 b = intercept of regression lines (on y-axis)
 $\langle p/p_{inv} \rangle$ = regression estimate of p ; i.e., the conditional estimate of the mean photograph proportion, given the inventory sample mean
 $s_{<>}^2$ = variance of $\langle p/p_{inv} \rangle$
 $s_{<>}$ = corresponding standard deviation
 $100\Delta/<>$ = relative variation of regression estimate in percent at confidence coefficient equal to 0.9

ORIGINAL PAGE IS
OF POOR QUALITY

TABLE 8-4.- INVENTORY AND PHOTOGRAPH SAMPLE DATA FOR
WATER PROPORTIONS

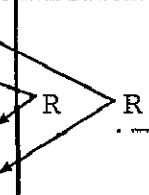
Statistical function, x	Simulated inventory estimate from 25 samples, $\hat{p}$	Aerial photointerpretation estimate from 25 samples, p	Regression estimate from simulated inventory, P_{inv}
$\bar{x}$	0.005	0.0084	0.010778
s^2	.00154	.000615	
$s_{\bar{x}}^2$	.00006	.000025	
$s_{\bar{x}}$	.002508	.004956	
$\Delta_{.9}$	.004292	.008479	
$100\Delta/\bar{x}$	85.83%	100.95%	
r^2		.64065	
m		1.5866	
b		.0004	
$\langle p/P_{inv} \rangle$			.017500
$s_{<}^2$			.000011
$s_{<}$			.003283
$\Delta_{.9}$			.005618
$100\Delta/<$			32.10%

Symbol definitions:

$\bar{x}$ = mean of the x_i
 s^2 = variance of the x_i
 $s_{\bar{x}}^2$ = variance of the mean
 $s_{\bar{x}}$ = standard deviation of the mean
 $\Delta_{.9}$ = half-confidence interval with confidence coefficient equal to 0.9
 $100\Delta/\bar{x}$ = relative variation of x in percent
 r^2 = coefficient of determination (fraction of sum squares about the mean that is removed by the regression)
 m = slope of regression line
 b = intercept of regression lines (on y-axis)
 $\langle p/P_{inv} \rangle$ = regression estimate of p ; i.e., the conditional estimate of the mean photograph proportion, given the inventory sample mean
 $s_{<}^2$ = variance of $\langle p/P_{inv} \rangle$
 $s_{<}$ = corresponding standard deviation
 $100\Delta/<$ = relative variation of regression estimate in percent at confidence coefficient equal to 0.9

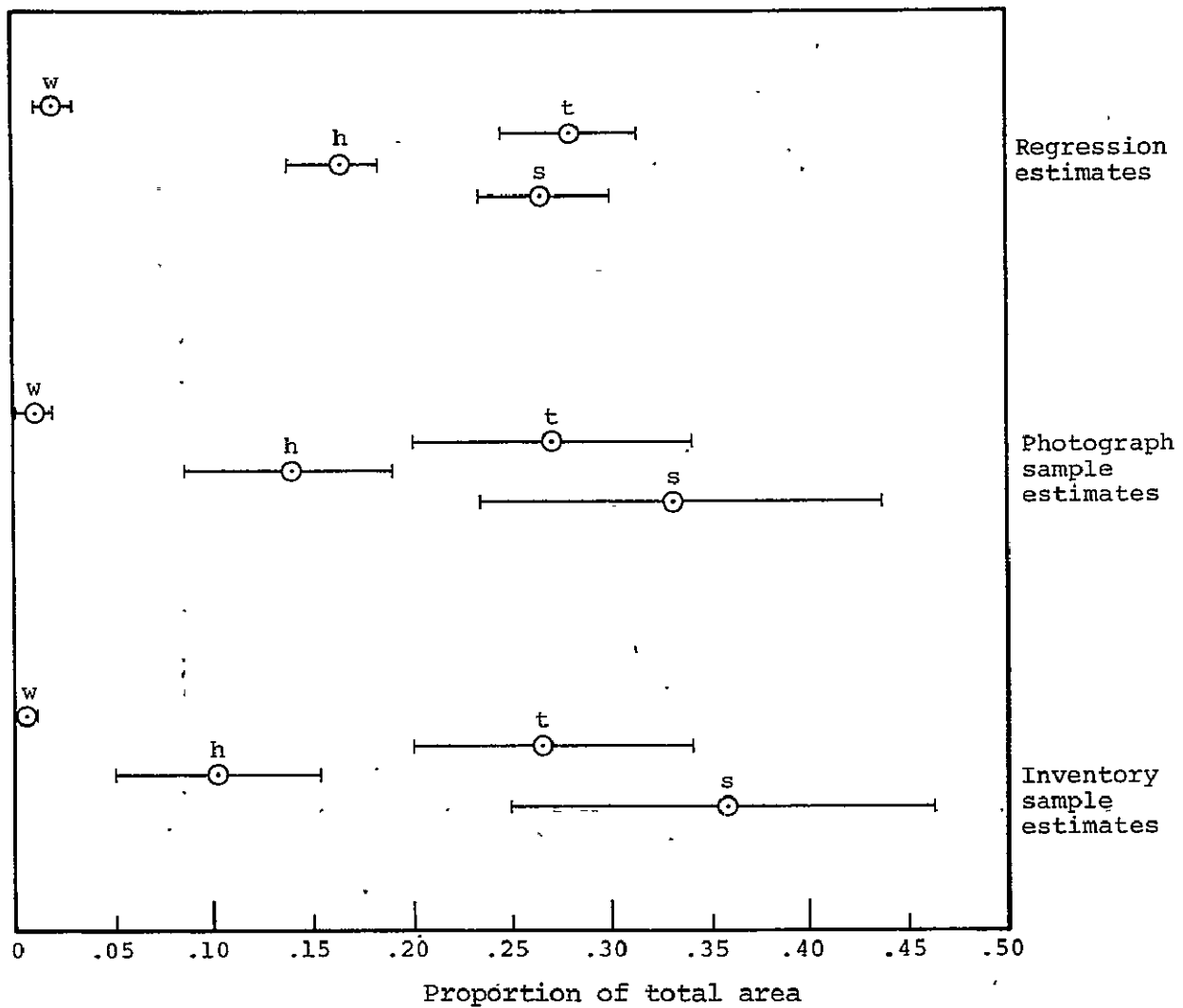
.017500
 .003283

TABLE 8-5.— RECAPITULATION OF LEVEL I AND LEVEL II PROPORTION ESTIMATES

Estimate type	Level II		Level I			
	Softwood	Hardwood	Forest	Tundra	Water	Other
August 1976 separability	0.415	0.132	0.547	0.256	0.020	0.177
September 1973 separability	.336	.193	.529	.436	.016	.019
Temporal separability	.309	.215	.524	.294	.010	.172
Temporal inventory	0.278	0.124	0.402	0.277	0.011	
Temporal inventory sample	.358	.102	.458	.268	.005	
Photograph sample (August 1976)	.338	.142	.477	.276	.0084	
Regression estimate	.268	.161	.431	.285	.0175	

NOTE: R is the regression transformation.

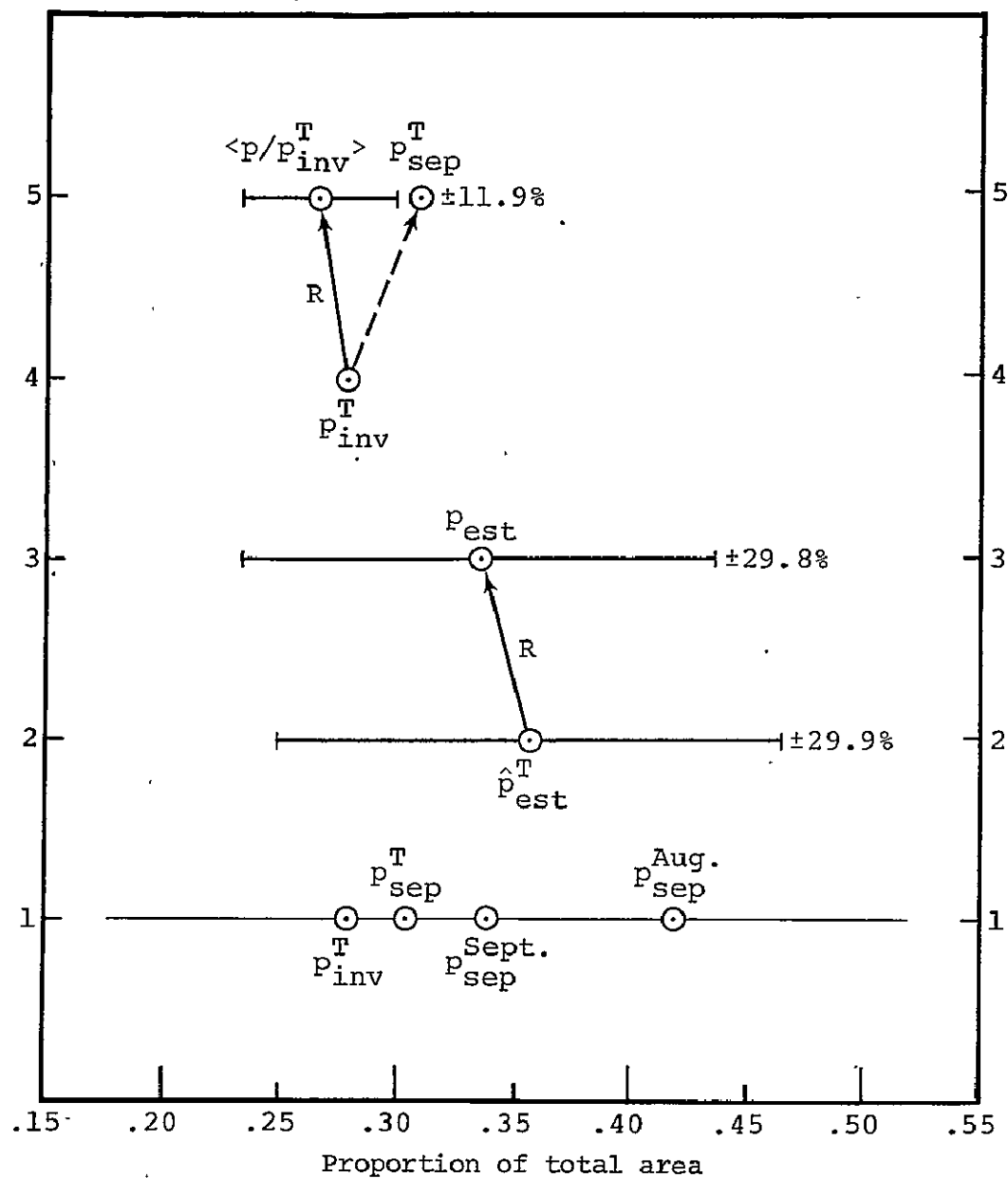
ORIGINAL PAGE IS
OF POOR QUALITY



Legend:

s - softwood
h - hardwood
t - tundra
w - water

Figure 8-1.- Summary of proportion estimates and 90-percent confidence intervals.



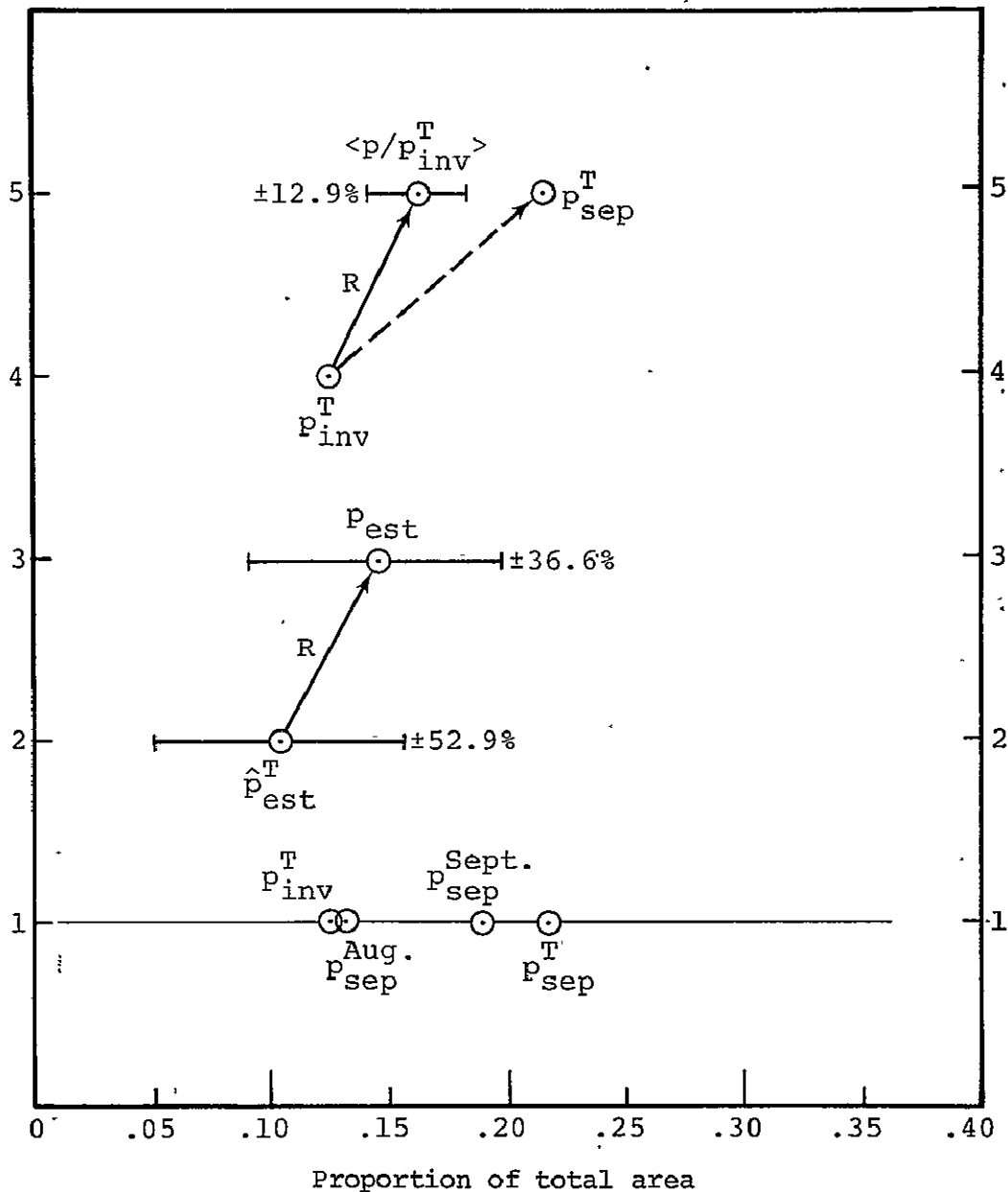
Legend:

p - aerial photograph proportion
 $\hat{p}$ - simulated inventory proportion
 est - statistical estimate
 inv - inventory
 sep - separability
 R - regression transformation
 T - temporal
 $\longrightarrow$ - actual transformation
 $\dashrightarrow$ - expected transformation

Line number:

1 - ADP inventory and separability estimates
 2 - simulated inventory estimate from 25 samples
 3 - aerial photointerpretation estimate from 25 samples
 4 - simulated inventory
 5 - regression estimate

Figure 8-2.- Proportion estimates for softwood.



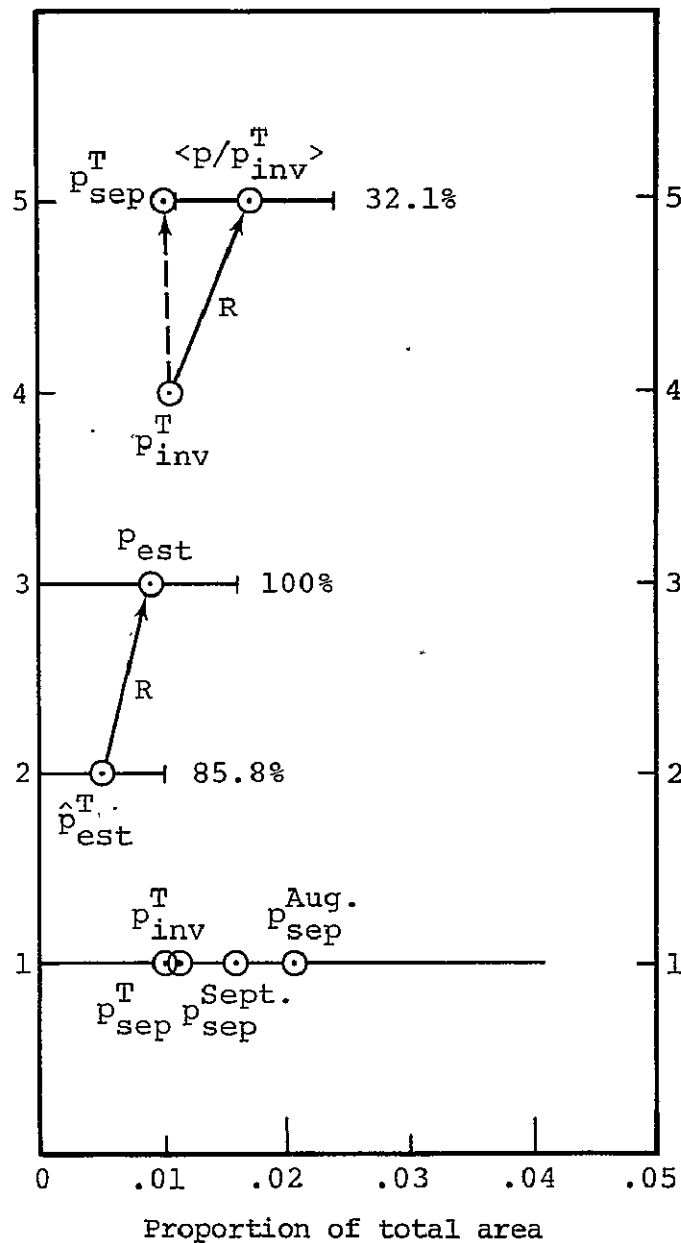
Legend:

p - aerial photograph proportion
 $\hat{p}$ - simulated inventory proportion
 est - statistical estimate
 inv - inventory
 sep - separability
 R - regression transformation
 T - temporal
 → - actual transformation
 ---→ - expected transformation

Line number:

1 - ADP inventory and separability estimates
 2 - simulated inventory estimate from 25 samples
 3 - aerial photointerpretation estimate from 25 samples
 4 - simulated inventory
 5 - regression estimate

Figure 8-3.- Proportion estimates for hardwood.



Legend:

p - aerial photograph proportion
 $\hat{p}$ - simulated inventory proportion
 est - statistical estimate
 inv - inventory
 sep - separability
 R - regression transformation
 T - temporal
 → - actual transformation
 --> - expected transformation

Line number:

1 - ADP inventory and separability estimates
 2 - simulated inventory estimate from 25 samples
 3 - aerial photointerpretation estimate from 25 samples
 4 - simulated inventory
 5 - regression estimate

Figure 8-5.- Proportion estimates for water.

9. CONCLUSIONS AND RECOMMENDATIONS

9.1 CONCLUSIONS

The conclusions resulting from the analysis of Site VI and the technical procedures are discussed in this section.

9.1.1 OPTIMAL DATE FOR LANDSAT IMAGERY

The Alaska site is located in the Arctic Circle. Therefore, it is unique among the TES sites in that, for all practical purposes, it has only two seasons: (1) the summer growing season, with about 20 hours of sunlight each day, and (2) the dormant winter season, with only about 4 sunlight hours each day. When the hours of sunlight increase to a sufficient number and the snow melts (around the end of April or the first day of May), the vegetation develops quite rapidly. The vegetation quickly goes into a dormant season around the end of September, when the number of sunlight hours decreases. Thus, imagery for distinguishing vegetative classes was available for only the 4 or 5 summer months.

An optimal date was not determined for the site through this study because imagery for only six dates was available. Three of these were eliminated because they did not meet one or more of the imagery standards set for TES. The three acceptable dates were August 27, 1976; September 3, 1973; and March 2, 1974.

The August 27, 1976, and September 3, 1973, imagery was chosen for the analysis. Although the two dates are in the same season, the difference in years offered some added separability when creating a temporal date. However, the enhancement was insufficient to warrant the extra cost.

The March 2, 1974, imagery was used as a separate data set. It resulted in an objective estimation of Level III spruce density measurements because the light snow cover provided a uniform background.

9.1.2 TYPE MAPPING ACCURACIES

Type separability study training-field accuracies showed good separation in the Level II features (softwood, hardwood, tundra, and water), using the September, August, and temporal data sets. The temporal data set had the highest overall accuracy (99.5 percent); however, none of the accuracies differed from the accuracies of the other data sets by more than 4.9 percent.

The Level III softwood density separation (dense and sparse) and the composition separation of tundra (grass and brush) were very diverse. This may have been caused by an insufficient number of pure training fields for the Level III classes. For example, if the dense spruce stands included several pixels of insect-damaged trees or permafrost inclusions, the resulting signatures would not represent the spectral reflectance from pure dense spruce because of the averaging effect of these "thin" pixels. This assumption has been supported by the low training-field accuracies of dense spruce throughout the range of the temporal data, suggesting that a clustering approach to Level III classification might prove helpful with this site. It was also found that grass tundra and brush tundra could be classified with a much higher degree of accuracy with the March and September/March data than was expected, probably because the snow was deep enough to cover all the grass tundra but was not deep enough to completely cover all the branches from the brush. Before any definitive conclusions can be made about the Level III classifications, a more thorough evaluation of the classification results should be made.

An evaluation of the simulated inventory study results indicated:

(1) the overall map accuracy was 72.4 ± 5.9 percent at the 90-percent confidence level and (2) the average error in the inventory class proportions was 2.04 percent when compared to the photograph class proportion, which was based on an interpretation of the aerial photographs.

The site familiarization task indicated that the Level II photo-interpretation was about 98-percent correct when compared to the ground checks. Thus, the correlation between the classification proportions and the proportions from the aerial photographs should be excellent.

The derived regression transformations were ineffective in recovering the loss of the Level I forest proportions and the loss of the Level II softwood and hardwood proportions. If the regression transformation is to be useful, the PSU sample set must be representative of the total site.

9.1.3 SPECIFIC SITE PROBLEMS

Burns have probably occurred at one time or another over most of the site. Vegetation was observed at all stages of growth and succession and has created much diversity in the spectral qualities of the site. It would be difficult, therefore, to select training fields in a 10-percent portion of the site that would be representative of all the spectral signatures in the site. Thus, some of the vegetation that should have been classified as softwood, hardwood, or tundra was not classified and fell into the "other" class. The pixels were then unclassified and placed in the "other" class. When time permits, categorizing the "other" class into specific classes should provide a worthwhile study.

The point at which mixed brush and trees become a pure stand was somewhat obscure on the Landsat data. The tundra classification resulted in a broad class which included woody and low-growing plants, forbes, and grasses. Some immature hardwood and softwood trees were also included in the tundra classification rather than in their respective classes.

The use of training fields selected from only 10 percent of the area for signature development did not adequately and efficiently cover the class variability.

9.1.4 FEASIBILITY OF ADP REMOTE SENSING TO LARGE AREA INVENTORY OF FOREST, TUNDRA, AND WATER

The total direct analysis cost of the Level II features in Alaska was 16.7 cents per square hectometer (7 cents per acre). This included the costs of the separability study, report writing, and other developmental studies. Therefore, it may be assumed that using remote sensing technology to inventory the forest, tundra, and inland waters of remote areas in the Alaska Boreal Ecosystem is feasible.

9.2 RECOMMENDATIONS

As a result of the processing performed on this site and previous TES results, the following recommendations are made:

- a. The Forest Service is presently compiling and tabulating data gathered in August 1977. A portion of the site used for TES is also included in the Forest Service test area. A comparison of the results should be made when these data become available.
- b. A comparison between the evaluation procedure for random sampling and systematic sampling should be analyzed.

- c. A major burned area appears on the August 1976 image but is not on the September 1973 image. A change detection study should be conducted on this area to observe the changes from vegetation to charred land and then the progression of the charred land through the natural changes of plant succession. It might also be possible to determine, to some degree, the intensity of the burn.
- d. A study comparing the spectral groupings found on the aerial photographs with the spectral clusters found on the Landsat imagery should be conducted. Such a study would provide an indication of the Landsat information content and would show the Landsat clustering to be more rapid and discriminating of subtle spectral features when classifying the scene at a level of detail finer than Level II.
- e. Most of Alaska is still a remote wilderness, and little of the forest land has been inventoried. Landsat imagery should be used as an excellent starting point for estimates of forest areas and for the first stage of stratification.

10. REFERENCES

1. Kan, E. P., ed.: Technical Analysis Procedures for the Ten-Ecosystem Study. Lockheed Electronics Co., Inc. (Houston, Tex.), LEC-9379, Dec. 1976.
2. Dillman, R. D.; and Ward, J. F.: Report on Site Selection for the Ten-Ecosystem Study (TES). Lockheed Electronics Co., Inc. (Houston, Tex.), LEC-8952, Oct. 1976.
3. Proposed Porcupine National Forest, Final Environmental Statement. Alaska Planning Group, Department of Interior, Dec. 1973.
4. Viereck, L. A.; and Little, E. L., Jr.: Alaska Trees and Shrubs. USDA Forest Service (Washington, D.C.), Agricultural Handbook no. 410, 1972.
5. Bliss, G. S.: Supplementary Climatic Notes for Alaska in Climate and Man. USDA (Washington, D.C.), 1941.
6. Sokolinkoff, Ivan S.: Higher Mathematics and Engineers and Physicists. McGraw-Hill Book Co., Inc. (N.Y. and London), 1941.
7. Dillman, R. D.: Ten-Ecosystem Study, Site I Report, Grand County, Colorado, Final Report. Lockheed Electronics Co., Inc. (Houston, Tex.), LEC-10691, Sept. 1977.
8. Kan, E. P.: A New Computer Approach to Map Fixed Forest Features and Postprocess Multispectral Data. Proc. ACSM/ASP Convention (Seattle, Wash.), Sept. 29 through Oct. 1, 1976, also in LEC-8061.